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THE BRITISH JOURNAL OF METALS

Vol. 53 No. 317 MARCH, 1956 Monthly: TWO SHILLINGS

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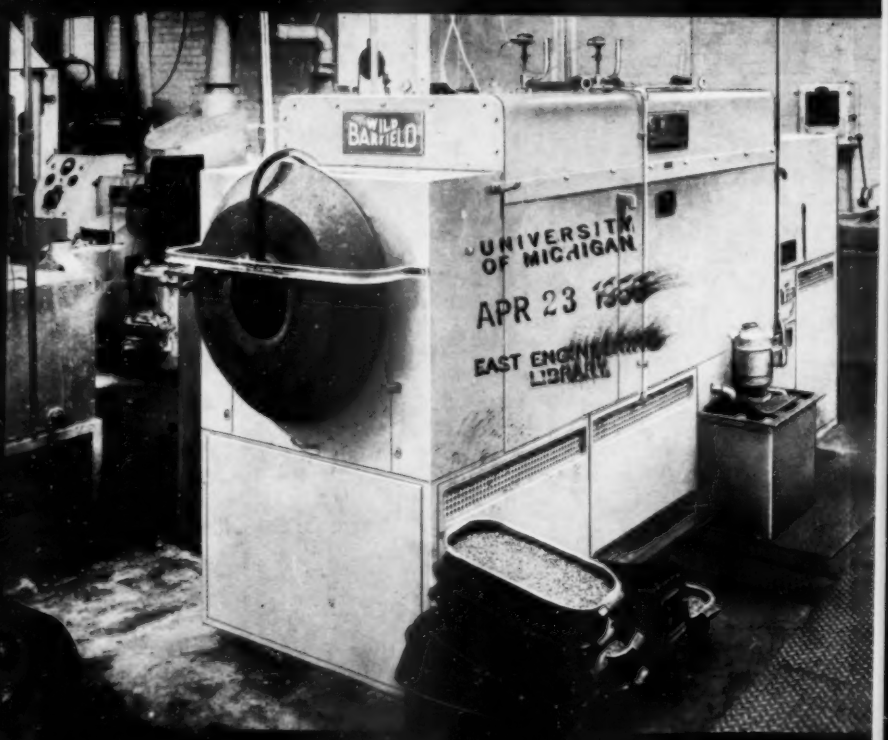

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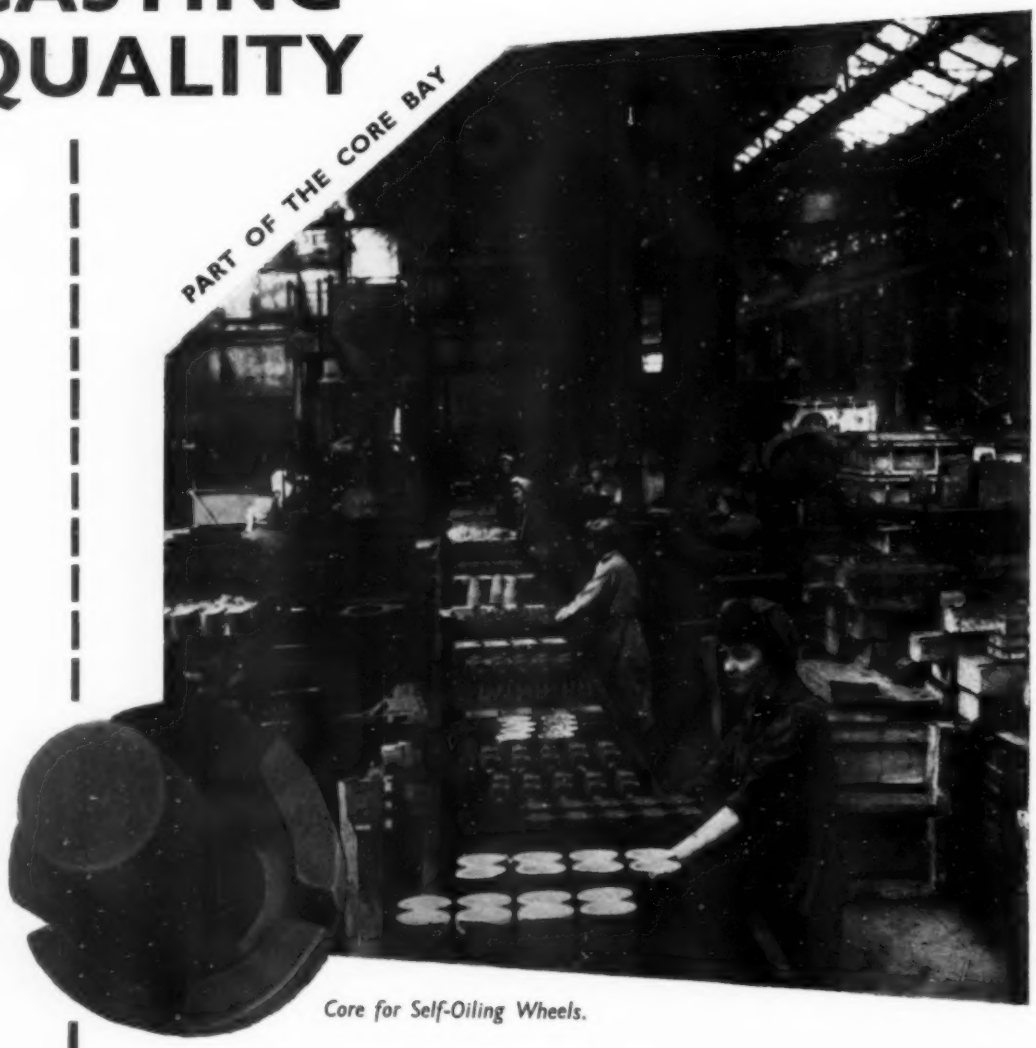

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INCORPORATING THE METALLURGICAL ENGINEER

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METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

MARCH, 1956 Vol. LIII. No. 317

Mechanical Handling

OVERLOOKED by the editorial offices of this journal, a metamorphosis is taking place, for what has for several years been a car park, made by levelling off a bomb-damage site, is to be transformed. What the final result will be has given rise to much rumour and speculation, and at one time it was believed that direct access to summer sunshine was to be cut off by a towering monument to that ever more flourishing institution, the Inland Revenue Department; more recent "information," however, is thought to justify a more hopeful outlook. In the course of the work to date, although the topography of the site has been changed considerably, by the removal and transposition of large quantities of earth and rubble, those music hall supports of the navvy—the pick and shovel—have been conspicuous by their almost total absence. The use of large labour forces equipped with hand tools is a thing of the past in civil engineering operations, to-day's worker having at his disposal such things as the dragline, mechanical shovel, bulldozer, crane, trencher, piledriver, dumper truck, and a host of other mechanical aids. This tendency had its beginnings before the war, but it received a tremendous impetus from the need for the utmost speed in building factories and making airfields: when the war ended, the labour position was such that the continued and increasing application of mechanical methods was inevitable.

It is not only in the civil engineering industry that mechanical handling has been so widely adopted, and there can be few industrial enterprises—no matter how small they may be—where it has found no application at all. As an importer of foreign goods with a relatively small, and fully employed population, Britain must use her shipping space, factories, warehouses and raw materials to the best advantage. Efficient handling and storage arrangements are, therefore, of urgent importance, and the biennial Mechanical Handling Exhibition—to be held at Earls Court from May 9th to 19th, 1956—will no doubt reflect the effect of this urgency on the users and manufacturers of handling equipment. Without attempting to forecast the detailed exhibits, attention may be drawn to some trends in the mechanical handling field.

In plant for the extractive industries the emphasis is upon automatic control and safety devices, better ways of dealing with difficult materials, and the more effective separation and collection of fumes and dusts. There are new refinements of detail design in the belt conveyors and aerial ropeways and cableways for which British manufacturers are traditionally renowned. Opencast coal mining has produced some interesting applications of earth-moving plant to the winning of coal and disposal of spoil and these, in their turn, have been applied in overseas installations to the mining of other minerals.

At the docks, railway termini, and airports, the imperative need for quicker turn round has led to many improvements in the capacity and efficiency of loading and unloading equipment. Centralised remote-control systems, devices for automatic weighing and levelling, and automatic relays for signalling danger and preventing damage, are among the more general features. Electric hoists fitted with improved slings and attachments, well-designed chutes for gravity movement with and without air-slides, and a variety of interesting mobile plant, are among the recent and current developments.

Fork-lift trucks are becoming increasingly versatile, being fitted with platforms, jibs, barrel-slings, prongs, rotating and stationary clamps, and innumerable other attachments, and the range of these already highly developed tools is being extended to include trucks capable of travelling at speed over rough ground and machines small enough to operate in the narrowest of gangways. Slewing masts and side-carriers will be available for work in congested areas, and quickly-replaceable masts and accessible moving parts will assist maintenance. Many machines will have central lubrication. Trucks are associated in most minds with pallets, and the principle of unit-load palletisation is now firmly established. There are, however, signs of a tendency to save both money and space by devising means of assembling and handling palletless unit-loads, under appropriate conditions.

Integration of the production and handling functions will probably rank with the unit-load system of handling as the most significant contemporary development in handling methods, and conveyors of all types and varieties are being adapted in increasing numbers for incorporation in production and assembly lines. Concurrently, refinements of detail continue to be introduced into the traditional heavy-duty belt conveyor handling its bulk loads of difficult and not-so-difficult materials. Reduction of belt wear is a permanent aim, in furtherance of which improvements in impact idlers and the composition of belting are being effected.

Portable and special-purpose conveyors are being developed continuously as needs arise, and flexibility is being increased to the degree at which the conveyor can no longer be said to have the limited function of transporting materials along a fixed route. This year will bring a further exploitation of possible shapes and constructional materials for the purpose of conveying substances that are dusty, hot, sticky, and otherwise troublesome.

(*continued on page* 116)

PRINTING TRADES DISPUTE

The publishers regret that owing to the printing trades dispute the publication of this issue has been delayed and the size slightly reduced. Every effort will be made to return to normal as soon as possible.

Meeting Diary

3rd April

Incorporated Plant Engineers, Edinburgh Branch. "Capacitors Pay Dividends": film by B.I.C.C., Ltd. Heriot-Watt College, Edinburgh. 7 p.m.

Institute of Metals, Oxford Local Section. Annual General Meeting, followed by "Nuclear Power," by DR. H. M. FINNISTON. Ballroom of the Cadena Cafe, Cornmarket Street, Oxford 7 p.m.

4th April

Institute of Welding, Manchester and District Branch. Annual General Meeting, followed by films on Stainless Steel Welding. Reynolds Hall, College of Technology, Manchester. 7-15 p.m.

5th April

Institute of Metal Finishing. Panel on "Technique of Racking and Jigging." A. WALMSLEY and OTHERS. The Engineers' Club, Albert Square, Manchester. 7-30 p.m.

Institute of Metals, London Local Section. Discussion on "The Properties and Uses of Titanium and its Alloys." 4, Grosvenor Gardens, London, S.W.1. 6-30 p.m. Preceded by the Annual General Meeting at 6 p.m.

Leeds Metallurgical Society. "Trends in Metallurgy," by PROF. A. G. QUARRELL. Large Chemistry Lecture Theatre, The University, Leeds, 2. 7-15 p.m.

6th April

Institute of Fuel, South Wales Section. "Modern Applications of Oil Firing," by R. J. BALDRY. South Wales Institute of Engineers, Park Place, Cardiff. 6 p.m.

10th April

Institute of Metals. Annual May Lecture by DR. WILLIS JACKSON. 4, Grosvenor Gardens, London, S.W.1.

11th April

Institute of Metals. Annual General Meeting. Presidential Address by MAJOR C. J. P. BALL. 4, Grosvenor Gardens, London, S.W.1.

North East Coast Institution of Engineers and Shipbuilders, Student Section. "Aluminium in Shipbuilding," by J. FULCHER. Bolbec Hall, Newcastle upon Tyne. 6-45 p.m.

Institution of Production Engineers, Peterborough Section. "The Metallurgist in Production Engineering," by E. BEVEN. The White Lion Hotel, Church Street (opposite Corn Exchange), Peterborough. 7.30 p.m.

Institution of Production Engineers, Western Graduate Section. "The Production of Light Alloy Castings," by J. R. HAYWARD and I. J. BIRCH. The Grand Hotel, Bristol. 7.30 p.m.

11th and 12th April

Society of Chemical Industry, Corrosion Group. Symposium on Prevention of Corrosion in Packaging and Storage: "Principles of Control at Atmospheric Corrosion," by E. LL. EVANS and E. G. STROUD; "Practical Methods of Preventing Corrosion in Packages," by J. FERRIGI; "The Selection of the Packaging Method," by F. A. PAINE; "Testing Packaging Materials," by R. B. TURNBULL; "Packaging Service Equipment," by E. L. HILL and D. J. EVANS; "Some Industrial Problems in Packaging and Storage," by J. F. KAYSER. The University, Birmingham. 2-30 p.m. April 11th; 9-30 a.m. April 12th.

12th April

Institute of British Foundrymen, Beds./Herts. Section. "Some Foundry Problems," by G. J. ROGERS. W. H. Allen, Sons & Co., Ltd., Bedford. 7-30 p.m.

Institute of Metals. All-day Symposium on "The Final Forming and Shaping of Wrought Non-Ferrous Metals." Discussion of Papers. 4, Grosvenor Gardens, London, S.W.1.

Institute of Welding, North Eastern (Tyneside) Branch. Annual General Meeting and "Structural Steelwork with Special Reference to Welding," by E. R. BOWERS. Mining Institute, Neville Hall, Newcastle-on-Tyne. 7 p.m.

Liverpool Metallurgical Society. "Non-Destructive Testing," by DR. R. F. HANSTOCK, followed by the Annual General Meeting. Liverpool Engineering Society, 9, The Temple, Dale Street, Liverpool, 7 p.m.

13th April

West of Scotland Iron and Steel Institute. "Thermal and Chemical Behaviour in the Open-Hearth Furnace," by DR. P. T. CARTER, W. G. CAMERON and PROF. R. HAY. 39, Elmbank Crescent, Glasgow. 6-45 p.m.

16th April

East Midlands Metallurgical Society. Annual General Meeting followed by "Some Developments in the Electrodeposition of Metals and Alloys," by PROF. J. W. CUTHBERTSON. Nottingham and District Technical College, Shakespeare Street, Nottingham. 7-30 p.m.

17th April

Institute of British Foundrymen, East Anglian Section. Annual General Meeting, followed by "CO_2 Process," by A. TIPPER. Central Hall, Public Library, Ipswich. 7-30 p.m.

18th April

Institute of Welding, West of Scotland Branch. Annual General Meeting and "Welding for the Chemical Industry," by T. WILLIAMS. Institute of Engineers and Shipbuilders of Scotland, 39, Elmbank Crescent, Glasgow. 6-30 p.m. for 7 p.m.

North East Metallurgical Society. "Steel Structures in Relation to Brittle Fracture," by DR. A. A. WELLS. Cleveland Scientific and Technical Institution, Middlesbrough. 7-15 p.m.

Society of Instrument Technology, Newcastle Section. "Surface Temperature Measurement," by T. LAND. Stephenson Building, Kings' College, Newcastle. 7 p.m.

19th April

Incorporated Plant Engineers, Blackburn Branch. "Electronics in Industry," by A. WORLAND. Golden Lion Hotel, Blackburn. 7-30 p.m.

Institution of Production Engineers, South Eastern Region. "Radio Active Materials in Industry," by DR. A. D. MERRIMAN. The Royal Empire Society, Northumberland Avenue (Craven St. entrance), Strand, London, W.C.2. 7 p.m.

24th April

Institution of Production Engineers, London Graduate Section. "The Finishing of Work by Polishing and Plating," by H. CANN. The Institution of Production Engineers, 10, Chesterfield Street, London, W.1. 7.15 p.m.

Society of Instrument Technology. "Dynamic Characteristics of some Neutralisation Processes and of Glass pH Electrodes," by PROF. IR. H. KRAMERS. Manson House, 26, Portland Place, London, W.1. 6-30 p.m. for 7 p.m.

25th April

Institute of British Foundrymen, London Branch. Annual General Meeting followed by "Casting of a Large Winding-drum Cheek," by A. W. BARTLETT. Waldorf Hotel, London, W.C.2. 7.30 p.m.

Society of Chemical Industry, Corrosion Group. Annual General Meeting. Spring Lecture: "Pitting and Cracking," by U. R. EVANS, F.R.S. S.C.I. Headquarters, 14–16, Belgrave Square, London, S.W.1. 6.30 p.m.

26th April

Incorporated Plant Engineers, Sheffield and District Branch. "Bearings and Bearing Failures," by MR. HOLLIGAN. Grand Hotel, Sheffield. 7.30 p.m.

Institute of British Foundrymen, Southampton Section. Annual General Meeting followed by "CO_2 Process and General Castings," by A. TIPPER. Technical College, St. Mary's Street, Southampton. 7.30 p.m.

Institution of Engineering Inspection, N.W. Branch. "Case Hardening and Heat Treatment in Cassel Salt Baths," by DR. THOMAS, with film. The Engineers' Club, Albert Square, Manchester. 7.30 p.m.

The Mains Frequency Coreless Induction Melting Furnace

Considerations Affecting Design

An announcement was made last year concerning an agreement which had been made between Otto Junker, G.m.b.H., of Lammersdorf, Germany, Ajax Engineering Corporation of Trenton, New Jersey, U.S.A., and Birlec, Ltd., of Birmingham, whereby mains frequency coreless induction furnaces would jointly be developed. Shortly afterwards, Birlec, Ltd., organised a series of meetings, in Sheffield, Birmingham and London, so that interested companies could learn more of the potentialities of this type of furnace. This first part of the report of the proceedings deals with the account presented by Mr. F. S. Leigh of Birlec of the theoretical and practical considerations affecting design.

THE basic principles of induction melting furnaces are well known, and this lecture is intended merely to explain as simply as possible, the differences arising from the application of a mains frequency supply at 50 or 60 cycles for energising the furnace, instead of using a supply at a high frequency—say 500 cycles or over.

Induction melting furnaces can be divided into two main classes—the core or channel type and the coreless type. In both cases one can consider the furnace as a simple transformer having two coils arranged concentrically. One coil is connected to a suitable A.C. supply whilst the other or secondary side is formed by the furnace charge, and can be regarded as a single-short circuited turn. On energising the primary coil, an alternating magnetic field is produced, a part of which will interlink with the secondary coil, thus producing a voltage across the terminals of this coil.

In the case of the channel type of furnace, a magnetic core is utilised to concentrate the magnetic field produced by the primary coil, and to ensure that the maximum possible proportion of this field will interlink with the secondary coil. In other words, the channel type of furnace is almost a true transformer, operating at a high efficiency of energy transfer from primary to secondary.

The coreless furnace—as its name implies—operates without a core, and therefore consists merely of two concentric coils. Since there is no magnetic core, a proportion of the field produced by the primary coil is lost and the energy transfer efficiency is correspondingly reduced. There are two methods of compensating for this factor, either to operate at higher frequencies or to increase the intensity of the magnetic field produced by the primary coil, and hence the current circulating in the secondary. The first method is, of course, exploited by the high frequency furnace and the second by the mains frequency coreless furnace. The following account deals with the latter type of furnace, particularly as regards factors involved in its design and manufacture.

Current Penetration

One of the most important factors governing the design of any induction melting furnace relates to current penetration depth, P, which increases rapidly with drop in frequency at the lower frequencies. This factor is utilised in calculating details of the furnace coil, by making the assumption that the charge is equivalent to a cylinder having a wall thickness equal to the current penetration depth. It follows that the greater the penetration depth—that is the greater the wall thickness of this imaginary cylinder—the lower will be the resistance for any given cylinder. As regards the inductor coil itself, the effect of greater penetration depth for the lower frequencies means that the resistance of the coil can be reduced by increasing its radial thickness.

Current penetration also influences the minimum diameter of the charge. Suppose the charge cylinder to be solid, and to have a radius smaller than the penetration depth for the particular material and frequency employed. Part of the current induced in the cylinder will then endeavour to circulate at a depth greater than the radius, and will try and oppose itself. The net result will be a reduction of the effective heating current circulating in the charge cylinder, and a reduced heating effect.

At first sight, it would therefore appear that the minimum size of cylinder should have a radius equal to the penetration depth. However, the penetration depth, when expressed as a definite dimension, is only valid if there is adequate depth of material behind it. In practice, it is found that the minimum radius of the solid charge cylinder should not be less than 1·5 times the penetration depth, and in a mains frequency melting furnace it is essential to have a charge made from comparatively large pieces, i.e., not less than 8 in. diameter for iron or steel.

Power Factor

The power factor of a furnace coil is determined accurately from a consideration of the coil resistance and reactance and the charge resistance and reactance. However, at low power factors, it is sufficiently accurate to take the power factor as being the ratio of the total effective resistance of the induction coil to its effective reactance. With decreasing frequency, the effective resistance and reactance will tend towards equality; in other words, the lower the frequency the better will be the power factor.

In practice, the mains frequency melting furnace will operate at a power factor usually twice as good as that of an equivalent high frequency furnace, and this means a considerable reduction in condenser correction kVA. As a guide, the power factor of a mains frequency coreless furnace for irons and steels would vary between 0·18

Fig. 1.—Typical coil assembly for 3 ton mains frequency coreless induction furnace.

and 0·25, depending upon size, whilst the corresponding high frequency furnace power factor would vary between 0·09 and 0·12.

Electrical Efficiency

The electrical efficiency of the furnace is given by the equation—

$$\text{Efficiency} = \frac{\text{Power developed in charge}}{\text{Power input to the inductor}}$$

In practice, the electrical efficiency of a 50 cycle furnace will be about 5% worse than that of an equivalent high frequency furnace, assuming a furnace size of about 15 cwt., or 2% with 3-ton bodies. However, this does not take into account the motor-alternator losses associated with the operation of a high frequency furnace. Allowing for this, there is a net gain in overall efficiency of about 10% in favour of the mains frequency furnace.

Stirring Effect

The stirring effect in an induction melting furnace is the result of mutual repulsion between charge and coil, the force acting on the charge being radially inwards. The magnitude of this force is a function of the currents circulating in the charge, and since this increases with lower frequencies, there is a maximum stirring effect with the mains frequency furnace. However, a judicious relation of power input to furnace size and arranging the furnace coil height to be somewhat lower than the charge height, reduces this turbulence. It has been found that the stirring effect is beneficial in certain directions, but this aspect will be dealt with later.

Minimum Furnace Size

As already explained, the mains frequency coreless furnace can only deal effectively with charges having a minimum cross-sectional size. This means that the crucible diameter and, hence, furnace coil diameter, may not be reduced below a certain value. The relationship between coil diameter and height is not particularly critical, and can vary between 0·8 and 1·2, but what is important is the amount of power which is to be transferred from the furnace coil into the charge. This dictates the ampere-turns for which the coil has to be designed. Finally, it is desirable to maintain the stirring effect within reasonable limits. This is achieved by limiting the amount of power input to a given charge, by arranging for the charge height to exceed the coil height.

Experience has shown that, taking all the above factors into account, the minimum size of furnace which can be operated efficiently under normal working conditions has a capacity of about 15 cwt. Obviously, however, it is possible to design and operate furnaces of considerably smaller capacities, but such units would work at a comparatively poor efficiency, and might not be regarded as suitable for everyday production work.

Furnace Coil

The coil of a mains frequency furnace is subjected to far greater mechanical vibration stresses than the coil of a similar size high frequency furnace. This is due to the very high 50 cycle magnetic field called for by the design, and great care must therefore be taken in ensuring adequate mechanical strength and rigidity. Fig. 1 shows a typical coil assembly for a 3 ton mains frequency furnace. It will be seen that the construction is essentially a unit construction, i.e., the coil and the associated magnetic shields are assembled between two heavy collars of rolled steel section, so as to form a self-contained unit.

The coil is wound from special extruded copper section. A hollow extrusion is used, thus combining electrical and cooling water conductors in one section. Great care is taken with the insulation, which consists of glass tape with silicone varnish. After winding the coil, it is impregnated and carefully stove dried.

Furnace Body

The furnace body is designed on conventional lines, as developed for high frequency furnaces of medium and large capacities. The framework is of structural steel construction and, since the furnace coil is magnetically shielded, there is no danger of the framework heating up due to stray fields.

The furnace is usually arranged for hydraulic tilting by means of two rams mounted one on each side of the furnace body: lip axis tilting is standard practice. A cover for the furnace crucible is usually provided, so as to reduce radiation losses from the top of the crucible as much as possible. This cover is hand-operated, and is raised and moved away from the crucible mouth in a single, easy motion. Normally, these furnaces are arranged for platform mounting in the same way as an orthodox high frequency furnace.

Electrical Control

Fig. 2 shows the schematic connection diagram of a typical mains frequency furnace. It will be seen that the capacitors required for power factor correction are arranged so as to provide for a fixed bank and a variable bank. The fixed bank provides sufficient capacitors to operate the furnace at minimum power input, i.e., on starting up from cold, whilst the variable bank gives the necessary flexibility to take care of the different electrical

conditions arising during the subsequent melting period. All capacitor switching is done by means of contactors, suitable interlocks being provided to ensure that the contactors are off-load operated. A static balancer is usually provided so as to give a 3/1 phase conversion as described in the following section.

The power input to the furnace is controlled within fairly wide limits by means of voltage control. For this purpose, it is usual to provide a three-phase tapped transformer between the supply mains and the static balancer. The transformer tappings can be either off-load or on-load operated, but the former is the cheaper arrangement and there does not seem to be any case for the more expensive on-load tap changing arrangement.

Instrumentation is quite straightforward, and follows established practice for all Birlec melting furnace installations. Apart from voltmeter, ammeter and kWh meter, there is usually a kVAr meter to show the operator that the furnace coil circuit has been properly tuned. Earth leakage protection, together with associated test equipment is invariably provided in accordance with Home Office recommendations.

Static Balancing

There are two methods available of providing a balanced three-phase load to the mains supply from the single-phase circuit of a mains frequency coreless melting furnace (see Fig. 3).

It will be seen that in Method B the furnace load, consisting of inductor coil and capacitors, is connected across one phase of the supply, say across B and Y. Across R and Y there is a reactor, tapped at a suitable point, and finally a capacitor is connected between B and the reactor tapping point. This arrangement has the drawback that the best power factor which can be achieved is 0·866, unless a supplementary three-phase capacitor is provided.

The alternative arrangement (Method A) provides for the reactor to be connected across B and R, the capacitor across phases B and Y and the furnace load across Y and R. Sufficient capacitors must be provided in this case to ensure unity power factor for the furnace circuit, and this is slightly more expensive.

From the furnace operator's point of view, Method A is preferable, since he will usually obtain a satisfactory three-phase balance at all available furnace inputs, provided he maintains the furnace coil circuit at unity power factor, or thereabouts, and adjusts the balancer to suit.

With Method B, it is only possible to obtain perfect balance at full load or any one particular load condition for which the balancer is designed. In other words, the operator has no control over balancing the three phases.

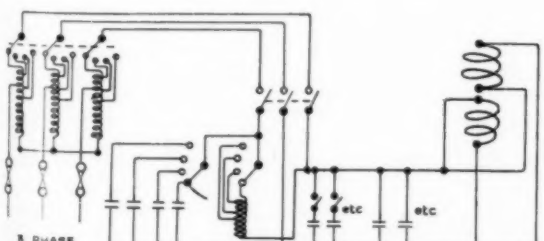


Fig. 2.—Schematic connection diagram of a typical mains frequency coreless induction furnace.

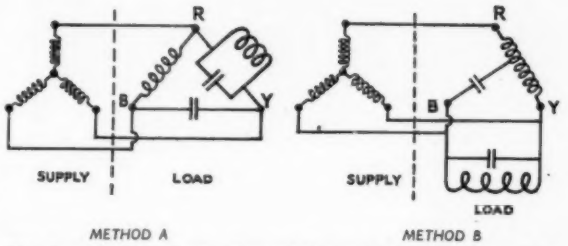


Fig. 3.—Two methods of providing a balanced three-phase load from the single-phase furnace circuit. The phase-rotation is R, Y, B, in each case.

It will also be seen that in Method A the balancer capacitor operates at full phase voltage, whilst with Method B the balancer capacitor voltage is somewhat lower—the theoretical value being 0·866 × phase voltage. Consequently, in this case the static balancer capacitor is likely to be a little dearer owing to the lower operating voltage.

As regards overall costs, there is very little to choose between the two methods, the slightly higher cost in the one case being offset by better phase balancing under all conditions, and by unity power factor operation.

Layout

The layout of the mains frequency coreless induction melting furnace follows very closely the practice established for high frequency furnaces. The furnace bodies are usually platform mounted, the platform being some 3–4 ft. above shop floor level, thus reducing foundation cost and at the same time providing a ready means of hand shanking from the furnace.

The furnace control panel is usually mounted on the platform and is therefore readily accessible to the operator. The furnace capacitors are mounted immediately behind the control panel in a suitable enclosure, together with the necessary contactors, transformers, switchgear, etc. Care must be taken to ensure adequate ventilation of the capacitor enclosure so as to prevent over-heating and consequent damage.

The size of the enclosure or sub-station is considerably reduced, since no high frequency motor alternator set is required, and this saving in space occupied is one of the valuable features of a mains frequency induction melting furnace installation.

The general arrangement should, if at all possible, provide for two furnace bodies to be operated alternatively from the same electrical equipment. This has the advantage that there is available 100% furnace standby capacity, and no production time need be lost for replacing a furnace lining.

Fig 4 shows the general arrangement of a 15/18 mains frequency coreless furnace supplied recently by Birlec, the first British mains frequency coreless furnace. This unit, which was designed for a rating of 250 kW and primarily intended for the melting of cast iron swarf, is installed at the works in Coventry of the British Piston Ring Co., Ltd., more or less as a pilot plant.

The melting rate achieved is of the order of 7 cwt./hr. and the furnace deals very effectively with very fine dry borings down to a mesh size of 200.* As is well known

* This may appear to be at variance with the earlier statement that for efficient operation the charge should consist of pieces 8 in. in diameter. Large pieces are used for the initial melt and borings are then added to the bath.

Fig. 4.—250 kW mains frequency coreless induction furnace recently installed by Birlec, Ltd., for melting cast iron swarf.

it is extremely difficult to deal efficiently with such finely divided metallics, and the makers are very pleased that their first installation should have coped so successfully with one of the most difficult of melting problems. As a matter of interest, the energy consumption with melting and super-heating to a temperature 1,450° C. is of the order of 580–600 kWh/ton.

Conclusion

The foregoing has outlined very briefly the main theoretical and practical considerations which go into the design and manufacture of a mains frequency coreless melting furnace, which will, it is believed, help to fill some of the gaps which exist in the range of melting equipment available to industry. It is unlikely that the mains frequency furnace will replace the high frequency furnace entirely, but it will compete successfully with the latter on the score of operating and capital costs.

The possibility of the channel type furnace being replaced by the coreless type has also been discussed. The channel type furnace is used in the aluminium industry for small sand and die castings, and for such an application, involving a comparatively low melting rate—say 200–500 lb./hr.—or for holding molten metal at temperatures, it is ideal. Where a large tonnage output is required to be taken up by a number of die casting stations, however, it would appear to be better to consider bulk melting in the mains frequency coreless furnace and then transferring the metal to channel type holding units. On account of its better electrical efficiency and lower capital cost, the channel type furnace will compete successfully with a coreless type furnace for certain applications, but other factors, such as melting rates and the effect of molten metal upon available refractories have an important bearing on this matter.

Specialised Rolling Equipment for Titanium

MARKING the first step in the development of a specialised fabricating facility devoted exclusively to the rolling and forging of titanium, the Titanium Metals Corporation of America announced recently the placing of an order for a Sendzimir reversing cluster mill for the cold rolling of titanium strip in widths up to 49 in. This unique unit will be designed specifically to cold roll large coils of titanium to the extremely accurate gauge tolerances and mirror finish long desired by the airframe industry. The mill will cost in excess of $3,000,000 and will be engineered by Allegheny Ludlum Steel Corp., one of the co-owners of T.M.C.A., and will be installed in an Allegheny Ludlum Pittsburgh-area mill.

Since its industrial birth some five years ago, metallic titanium has been rolled and forged on equipment designed primarily for stainless steel. Order tonnages have now risen to such volume, according to T.M.C.A., the major producer, as to justify the engineering of major conversion equipment for titanium adapted to the characteristics of this very tough, strong and lightweight metal. Only one 49 in. Sendzimir mill is in operation, on stainless steel. The engineering of such a precision unit to titanium is a forward step without precedent, and is the first industry move toward specialisation in mill equipment to convert titanium ingots.

Titanium Metals Corporation of America, jointly owned by National Lead Co., and Allegheny Ludlum Steel Corp., has reported that its major sponge metal and ingot facility at Henderson, Nevada, continues to operate at capacity level. The price of titanium sponge has been reduced more than 23% by T.M.C.A. during 1955. The announcement of the industry's first move to expand and specialise in major finishing facilities, promises further improvements in the quality and cost of titanium, which is in critical demand for high-priority jet engines, fighter and bomber airframes, long-range ballistic missiles, atomic energy and chemical processing equipment. Among the many current applications of titanium are major components of the J-57 gas turbine engine, the B-47 and B-52 jet bombers, the F-100, F-101 and F-102 jet fighters, and the DC-7, DC-8 and 707 civilian transports.

Wolf Australian Plant

IN order to satisfy the demand in Australia for Wolf portable electric tools, a manufacturing company, Wolf Electric Tools (Australia) Pty., Ltd., has been formed with a registered capital of £A.250,000 and a factory constructed on a site of adequate size to allow for future expansion. The site is located approximately eight miles from Sydney. Initially, the factory is to specialise in the assembly of Wolf Cub Homecraftsman electric tools from components shipped by the British operating company, Wolf Electric Tools, Ltd. Later plans, however, include the manufacture of Cub equipment together with Wolf industrial tools from Australian-produced components.

Copper and Copper Alloys

A Survey of Technical Progress During 1955

By E. Voce, Ph.D., M.Sc., F.I.M.

Copper Development Association

Continued progress has been made in the past year in the metallurgy of copper and its alloys, and in the various sections of this review the author discusses the principal items of interest concerning such aspects as raw material resources, extraction, fabrication, finishing and properties.

THE year just ended, like the previous one, has witnessed considerable labour unrest in the copper-producing areas, and these together with other economic factors, have contributed to restrict the available supplies of the metal. Though the diminution has not been excessive in comparison with the total output, it has been sufficient, in a delicately balanced market, to influence the price, which has risen sharply during the year. The situation has recently been reviewed by Prain,[1] who points out that, under the hoped-for more quiescent conditions of the foreseeable future, there is likely to be an appreciable increase in production, and perhaps even a slight surplus over consumption. This should lead to more stable prices, probably at a somewhat lower level than at present. He emphasises that, ideally, the price of the metal should be low enough to deter excessive competition from substitute materials, and, at the same time, sufficiently high to encourage mine development and the expansion of production.

Against the background of the rather unusual conditions brought about by the economic situation just outlined, the normal progress of technical development in science and industry has been well maintained, and many publications of merit and interest have appeared.

The Production of Copper

Copper Mines and Deposits

From areas scattered all over the world, come indications of increased production of copper from existing sources, and of the development of new projects. The newer mines of Northern Rhodesia at Chibuluma, Baluba, Chisangwa, Bancroft and Kansanshi have been concisely described in general terms,[2] and it has been announced that Bancroft is expected to double its initial output by 1960.[3] By that date it should be producing more than 85,000 tons of copper annually, thus making it one of the world's major suppliers.[4] Open pit mining is being put into operation at Nchanga, and an excellent description of the project has been written by Nelems.[5]

In Canada, the vast expanse of the Pre Cambrian Shield still undoubtedly conceals immense ore deposits of many kinds. In the Temagami Island area, Ontario, drillings have indicated an estimated 1·3 million tons of nickel-copper-cobalt ore; the copper grade is stated to range from 1·2 to 1·65%.[6] In a hitherto unexamined district off the Mount Laurier Highway, Quebec, copper-nickel has also been reported, with a showing of 2·0% copper over a considerable area.[7] Promising copper-nickel deposits in the Bird River region, Manitoba, have been briefly described by Davies.[8] Further work has been done on the Gaspe copper deposits, where the ore reserves are now estimated at 70 million tons, containing about 1·3% copper; a smelter is being built there.[9] Developments are also reported from British Columbia, notably on the Britannia, Granby and Grandice properties.[10]

In South America, exploration has continued at the new Indio Muerto and Toquepala mines in Chile and Southern Peru, respectively; each of these is stated to contain some 400 million tons of ore averaging 1·0% of copper.[11] The Toquepala project is expected to produce 140,000 tons of blister copper per annum.[12] The Chilean Ministry of Mines has announced that the Africana mine, owned by the Anaconda Copper Company and located near Santiago, will start operations this year with an estimated annual output of 20,000 tons of copper concentrate.[13]

Turning to other parts of the world, deposits of copper ore have been found in Sweden and in Swedish Lappland[14] and also in Burma,[15] while Israel is to produce 6,570 tons of cement copper per annum from King Solomon's copper mines at Elath, mainly for export to Europe.[16] Notes on the copper industry of Persia have appeared,[17] with special reference to the mining and smelting operations at Abassabad, Sabzevar, Zendjan and Talmessy, and to the refining plant at Ghani Abad. Simmons[18] has reviewed the copper industry of Australia, pointing out that, at the present rate of extraction, the known ore reserves will last no more than 12 years; on the other hand, the latest quarterly review of the Australian mineral industry indicates extensive reserves both at Mount Isa and at Mount Lyell.

A recently published O.E.E.C. report on copper smelting and refining in the United States[19] covers the subject thoroughly, and ends by emphasising the essential function of research in increasing the efficiency of metallurgical operations.

Technical Developments

The oxygen flash smelting process for the treatment of copper sulphide concentrates has now been in full operation for over a year at the International Nickel Company's plant in Canada. A detailed review of the history of the process, and of the plant now in use, has been given by the staff of the smelter,[20] and a summarised account of this new development has also been published.[21] Concentrates are now being smelted by the International Nickel Company, at the rate of 1,000 tons a day, necessitating the supply of 325 tons of 95% pure oxygen every 24 hours.

Forward and Mackiw[22] have published further information concerning the chemistry of the ammonia pressure leaching and precipitation process for the extraction

of nickel, copper and cobalt powder from sulphide concentrates, reference to which has been made in several earlier surveys, and an Australian patent on the subject has appeared.[23] One of the most recent papers in this field, by Schaufelberger and Roy,[24] describes experimental work on the separation, by hydrogen precipitation, of copper, nickel and cobalt in acid solution; the authors conclude that "copper is easily separated from nickel and cobalt (by reduction with hydrogen) probably better in acidic solution than in ammoniacal."

The hydrometallurgy of copper-zinc sulphide concentrates practiced at the Kosaka smelter of the Dowa Mining Company of Japan has been described by Kurushima and Tsunoda.[25] They discuss the introduction of a new type of roaster, which has enabled the recovery of both copper and zinc by roasting in a fluidized bed, and state that 2,400 tons of concentrates are being treated per month. The hydrometallurgy of copper oxide ores containing 3·5% of copper by the Compania Minera Sali Hochschild in Copiapo, Chile, is the subject of a paper by Wendt[26], which includes a comprehensive flow sheet of the leaching techniques employed.

In connection with the froth flotation of siliceous copper ores containing chalcocite, chalcopyrite and bornite, a frothing agent consisting of an ester of an alkane dicarboxylic acid has been patented.[27] Another patent,[28] from a German source, concerns the treatment of complex copper-nickel-iron or copper-cobalt-iron mattes. The matte is worked up by adjusting the sulphur content, a metallic fraction containing iron and the nickel or cobalt and a non-metallic fraction consisting of mixed copper and iron sulphides being obtained.

In the fire refining cycle, the Norddeutsche Affinerie has patented a substitute for the normal poling technique.[29] The oxidised melt is stirred by a stream of inert gas, preferably steam, while under a reducing atmosphere containing at least 5% of hydrogen or carbon monoxide. The occurrence and influence of inclusions of stannic oxide, arising from scrap, in fire refined copper have been studied in detail by Széki and Hegedus,[30] who demonstrate the difficulty of removing heavy particles of this substance from the melt, and describe its effect on the mechanical properties of copper sheet.

An informal discussion[31] of the treatment of swarf and residues has provided some useful general information on this subject, while an article on the sorting of copper alloy scrap[32] claims that very precise information can be obtained by means of simple tools, such as a file and drill, in the hands of an experienced operator.

Foundry Practice

General Foundry Technique and Quality Control

A recent review of productivity in the bronze and brass casting industry[33] indicates that technological advances have been considerable during the past few years, especially in such directions as the use of aluminium alloy match plates, shell moulding, the carbon dioxide process, and nitrogen degassing. On the other hand, the review urges the desirability of paying greater attention to job simplification, mechanisation, costing and work study. In this connection, a useful foundry incentive scheme has been described by Johnston.[34]

A manual published by the British Bronze and Brass Ingot Manufacturers' Association[35] covers the composition, properties and uses of copper-base alloy castings to B.S. 1400. A feature of the book is an excellent description of foundry technique, including types of furnaces, melting operations, degassing procedures, and running and feeding methods. Another booklet which should prove of value to foundrymen dealing with copper-base alloy castings pays attention to the factors affecting melt quality and pressure tightness, with particular reference to 85/5/5/5 leaded gunmetal.[36]

An illuminating paper by French[37] discusses melt quality tests for copper-base alloys. He emphasises the complexity of the problem, especially in relation to the factors which influence the mode of solidification, for, with these under control, the effect of gas content can be minimised. In this connection, Chalmers[38] has given an excellent exposition of the processes of melting and freezing from the fundamental point of view. Pell-Walpole discusses the relationship between pouring temperature, porosity and tensile strength of sand-cast bronze.[39] He shows that, even with degassed metal and dry moulds, there is an increase in porosity and a decrease in strength as the pouring temperature is raised. Free moisture in the mould leads to similar results, but combined moisture gives a more complex relationship, and it is shown that a mould coating consisting of a suspension of alumina and plumbago in tar oil is effective in minimising porosity. Keller and George[40] also attribute porosity to combined moisture in moulding sand.

A further investigation of porosity, structure and tensile properties of tin bronzes and gunmetals is that of Cibula,[41] who studied the effect of grain refinement on these properties. It was found that, because of the unfavourable distribution of porosity, grain-refined castings were characterised by comparatively poor pressure tightness and mechanical properties.

Gas porosity in aluminium bronze was the subject of an investigation by Schwietzke.[42] His experiments showed that pure hydrogen was not easily absorbed by molten 10%-aluminium bronze, and that the dry gas produced no porosity even after being passed through the alloy at 1,100° C.: only when the temperature was raised to 1,250° C. did hydrogen give rise to appreciable porosity in the casting. Steam, on the other hand, gave excessive porosity after bubbling through the melt at 1,100° C. The effects of "degassing" aluminium bronze with nitrogen, chlorine or phosphorus were also illustrated.

Individual Casting Methods

It is interesting to learn that an experimental unit for continuous casting of brass strip, based on the older Hazelett process, has been built in America.[43] The mould surfaces consist of two facing conveyor belts which are water cooled.

Two methods of centrifugal casting are in common use, one using a cast iron or steel mould and the other a rammed sand lining inside a metal container. A new process[44] combines the advantages of these methods by employing a metal mould lined with a thin coating of resin-bonded sand. It is, moreover, claimed[45] that centrifugal castings of exceptional length and quality can be made by the use of special sprayed coatings on the internal walls of the mould. Another new centrifugal casting process employs a water-cooled mould.[46] Mohler[47] has described the centrifugal casting of sleeve bearings in general terms, while an interesting technique has been proposed for the manufacture of air cooled internal combustion engines by a centrifugal method.[48] According to this invention, copper and iron are poured together

into a rotating mould, when the heavier copper is flung outwards to form the cooling fins while the lighter iron remains at the cylinder walls.

It is of interest to study a review of die dressings employed for pressure die casting machines.[49] The author describes a number of dressings which provide limited protection against high melting point alloys, including the copper-base materials, and suggests that more lasting protection can be obtained from an application of sodium silicate, followed by a suspension of powdered chalk or talc in any light mineral oil.

An ingenious process for manufacturing aluminium bronze chain by gravity die casting involves casting links in sets of three. These are joined together by casting an intermediate link, and long lengths are so assembled[50].

Though vacuum melting has not been widely applied to copper and copper-base alloys, Scholefield points out in a historical review[51] that this technique was early employed by the Heraus Vacuum Schmelze A. G., in the preparation of beryllium-copper alloys, with and without nickel. A logical development is the use of vacuum melting for the degassing of metals, and Bishop, Layne and Pellini[52] claim that sound castings can be made in this way from bronzes and gunmetals.

Modern Moulding Techniques

Reviews of shell moulding practice[53, 54] and of precision casting by the lost wax process[55] have appeared; that by Rice[53] on shell moulding being the result of intensive study, largely in foundries now using the process. There can be no doubt that shell moulding is rapidly increasing in popularity among founders of bronze and brass.

The carbon dioxide method of curing sand moulds and cores has been commented upon in previous surveys, and to the papers already reviewed should be added recent contributions by Tipper and Talbot. Tipper[56] describes the use of the process in British foundries, including one producing gunmetal and bronze valves and steam fittings; he emphasizes the considerable saving in production time which it can effect. Talbot[57] gives a detailed account of the introduction of the carbon dioxide process at the foundry with which he is associated, where some copper-base alloys are produced; he writes enthusiastically about the advantages of the method, laying emphasis on the saving of space. Atterton[58] points out that the process can be introduced into the average foundry for a very small capital outlay, while Schumacher[59] reviews its progress in Germany.

Another interesting foundry development is the use of glass moulds for the production of small precision castings which are claimed to have "exceptional surface finish and dimensional tolerances equal to investment castings."[60] Silica glass powder is mixed with water to produce a casting slip, and no binder is required; the slip is poured into a porous plaster mould, which absorbs the water and leaves a glass shell which can be removed from the mould and fired.

Foundry Alloys

Vaders[61] discusses the production and properties of a range of cast silicon bronzes containing arsenic, antimony, lead, or other elements, in addition to silicon. He maintains that all these alloys have advantages over the tin bronzes, recommending particularly those based on copper, silicon and lead.

McIntyre[62] has described in detail British practice in the production of aluminium bronze castings. His paper contains much practical information.

Refractories for Induction Furnaces

A valuable paper, based on long practical experience, has been published by Cook, Cowley and Broadfield[63] on refractories suitable for melting copper alloys in low frequency induction furnaces. They emphasise the fact that the performance of linings formed by the normal layer-ramming technique depends very largely on the skill and experience of those who carry out the work.

Refining

Thews[64] recommends calcium sulphate and the oxides of manganese for the removal of aluminium from zinc-bearing copper-base alloys, while Cirou and Le Thomas[65] have compared the efficiencies of sodium and magnesium for desulphurising leaded gunmetal after melting in oxidising and reducing atmospheres.

Stresses in Castings

A paper by Portevin and Pomey,[66] presented at the International Foundry Congress in London last year, describes procedures for the detection and measurement of residual stresses in castings. The authors also consider the factors which promote and modify the state of stress, and refer to both ferrous and non-ferrous castings as illustrative examples.

Fabrication

Hot Working

A detailed study of the hot stamping of metals including copper, brass and aluminium bronze has been made by Godtschalck[67] who discusses the principal factors and variables involved in the different stages of deformation of the metal. A small-scale research on the hot pressing of a leaded nickel brass of composition 52% copper, 6% nickel, 41% zinc and 1% lead has been conducted by Bovet.[68] He has shown that the temperature of pressing must be between 800 and 820° C. In a further article concerned with hot stamping,[69] it has been reported that the production of multi-cored brass stampings may be achieved by means of a direct action press in conjunction with a sub-press unit which has recently been designed. The unit enables a standard press to be converted into a side-action press which is able to core in two planes if required. A recently published book by Kyle[70] gives an up-to-date account of the modern closed-die forging process. Though concerned mainly with steel, it contains a section on non-ferrous metals, including copper alloys.

A patent by Properzi,[71] the originator of the continuous casting machine which bears his name, covers an apparatus for the rolling of metal wires and rods. It consists of a train of rolls arranged closely behind one another, each pass comprising three rolls inclined at 120° to each other, and considerable advantages over the normal methods are claimed. Starkey[72] describes guides and strippers for modern rod and bar mills. Though he is concerned primarily with the rolling of ferrous metals, similar plant could doubtless be adapted to the production of copper rod.

Cold Rolling

Whitton and Ford[73] have investigated the effects of lubrication on surface friction in the cold rolling of brass and copper strip, among other metals, using both smooth and rough rolls. They determined the coefficient of

friction under a variety of conditions, and found that values of roll force and torque calculated from these results agreed satisfactorily with those obtained by direct measurement. Electronic methods have been used to measure the thickness of copper strip for car radiators.[74] The reliability of the apparatus will be appreciated from the statement that duplicate coils of copper from the same mill gave identical chart recordings, the pattern being a " signature " of the mill on which the copper was rolled.

Wire Drawing

At the Joint Metallurgical Societies Meeting held in London last year, the problems of high speed wire drawing were discussed. A recent report of the meeting[75] has summarised the topics, which included British and American views on the types of machine employed, machine design, spooling speeds, lubrication, and a number of other points of general interest to those concerned with the high speed drawing of wire. Fluid lubrication in wire drawing has been reviewed by Christopherson and Naylor,[76] and their article includes a useful table giving some results of drawing tests on soft copper wire ; figures for drawing speed, lubricant flow, drawing force, friction in the die and other variables are included. The equipment for the production of rectangular section copper wire is discussed in a recent article.[77] Round sectioned wire is rolled to within 15% of the required final thickness and drawn through a tungsten carbide die of rectangular section in one operation. Speeds up to 2000 ft./min. may be obtained. The production of resistance wire, including cupro-nickel, is described by Stryker,[78] covering all stages of manufacture.

Cold Press-Work

Maréchal[79] has investigated a rolling defect in 67:33 brass which led to intercrystalline cracking of the sheet during press-work operations, and to laminated fractures under tensile test. He ascribes the trouble to the formation of the β-phase under certain conditions of working and heat treatment.

In general, brass of moderately large grain size, consistent with the absence of the " orange peel " defect, is preferred for deep drawing on account of its enhanced ductility. Turner and Banno[80] have, however, described a special continuous annealing process, claiming that, by its use, the advantages of high ductility can be combined with those of small grain size.

Stickney and Richards[81] have reported that die wear experienced in deep drawing beryllium-copper is largely dependent on the presence of a layer of beryllium oxide on the surface of the strip which is primarily formed during solution heat treatment.

Singer[82] assesses the factors affecting the choice of hydraulic or crank presses for cold working operations.

Tube Production

The formation of non-ferrous tubing at high speed from rolled strip by an automatic welding technique seems to be gaining popularity in America[83, 84] where several machines have been installed for the purpose. Speeds range from 40 to 120 ft./min., and it is stated that a wide variety of brasses and other copper alloys can be processed by the technique.

Mention must be made of the large new plant for the production of copper and copper alloy tubes recently installed at Kirkby.[85] It ranks among the best equipped in the world today.

Annealing

A recent installation which is designed for the semi-continuous bright annealing of copper wire as delivered from the drawing machines has been described.[86] The unit is capable of an output of 100 tons per week.

An electric furnace recently brought into service in this country for annealing copper tubes has been discussed,[87] whilst some details of furnace design and operation by an American firm have been reported by Peterson.[88]

(to be continued)

REFERENCES

The Copper Development Association regrets that it is not in a position to make available, on loan or otherwise, any of the books or papers listed below. Anyone requiring to consult these should apply to one of the Technical Libraries in his locality, from whom photostat copies may also be obtainable.

1 Prain, R. L. The Outlook for Copper—I and II. *Financial Times*, 1955, Nov. 29th, 30.
2 Anon. Northern Rhodesia's New Copper Mines. *Colonial Geology and Mineral Resources*, 1953–4, **4** (2), 180.
3 Anon. Bancroft to Double Capacity. *Metal. Bull.*, 1955 (3966), Feb. 4th, 18.
4 Bancroft Mines, Ltd. Doubling of Initial Output at Bancroft Copper Mine. *The Engineer*, 1955, **199**, May 13th, 660.
5 Nelems, H. E. Open Pit Mining at Nchanga. *Optima*, 1955, **5** (1), Mar., 6.
6 Anon. Temagami Hopes to Develop Nickel-Copper-Cobalt Mine. *Northern Miner*, 1955, **41**, Aug. 25th, 17.
7 Anon. New Metal Find Could Be Major. *Northern Miner*, 1955, **41**, Aug. 18th, 1 and 16.
8 Davies, J. F. Copper-Nickel Deposits of the Bird River Area, Manitoba. *Precambrian*, 1955, **28**, Mar., 6–8.
9 Gaspé Copper Mines, Ltd. and Noranda Mines, Ltd. Gaspé Copper Deposits. *Precambrian*, 1955, **28**, Feb., 26.
10 Cross, G. C. British Columbia Holding Its Ground. *Precambrian*, 1955, **28**, Feb., 6–8.
11 Greenlay, C. E. and Sherritt-Gordon Mines, Ltd. Metal Production Rapidly Expanding (Lynn Lake Mine Copper Deposits). *Precambrian*, 1955, **28**, Feb., 16.
12 Anon. Peru. *Metal Industry*, 1954, **85**, Nov. 12th, 418.
13 Anon. New Chilean Mine. *Metal Bull.*, 1955 (3969), Feb. 15th, 20.
14 Anon. New Copper Ore Deposits. *Machinery Lloyd*, 1954, **26** (23A), Nov. 13th, 134.
15 Anon. Burma's New Sources of Coal and Copper. *Eastern Metals Review*, 1954, **7** (47), Dec. 27th, 965.
16 Anon. Israel to Produce Cement Copper. *Metal Bull.*, 1955 (3979), Mar. 22nd, 19.
17 Ernemann, A. Mining and Smelting in Persia. *Metal Bull.*, 1954 (3949), Dec. 3rd, 15.
18 Simmons, A. L. The Copper Industry in Australia. *Metal Progress*, 1955, **61** (1), Jan., 87.
19 Organisation for European Economic Co-operation. Copper Smelting and Refining in the U.S.A. Tech. Assist. Mission, No. 85, vol. 1. Paris, O.E.E.C., Oct., 1954.
20 International Nickel Co. Oxygen Flash Smelting Swings into Commercial Operation. *J. Metals*, 1955, **7**, June, 742.
21 International Nickel Co. Oxygen Flash Smelting of Copper Sulphide Concentrates. *Metallurgia*, 1955, **52**, July, 33.
22 Forward, F. A., and Mackiw, V. N. Chemistry of the Ammonia Pressure Process for Leaching Ni, Cu and Co from Sherritt Gordon Sulphide Concentrates. *J. Metals*, 1955, **7** (3), Mar., 457 ; *Trans. A.I.M.E.*, 1955, **203**.
23 Sherritt Gordon Mines, Ltd. (Inventors : V. N. Mackiw, V. Kunda and Wei-Cheng-Lin). Recovery of Metal Values from Solutions. Australian Pat. Appln. 23762/53.
24 Schaufelberger, F. A. and Roy, T. K. Separation of Copper, Nickel and Cobalt by Selective Reduction from Aqueous Solution. *Trans. Inst. Min. Met.*, 1954–55, **64** (7) ; *Bull. Inst. Min. Met.*, 1955 (581), Apr., 375.
25 Kurushima, H. and Tsunoda, S. Hydrometallurgy of Copper-Zinc Concentrates. *Trans. A.I.M.E.*, 1955, **203** ; *J. Metals*, 1955, **7**, Sect. 1, May, 634.
26 Wendt, W. Wet Metallurgical Treatment of Oxide Copper Ores by the Compania Minera Sali Hochschild in Copiapo, Chile. *Berg-und Hüttenm. Monatsh.*, 1955, **100**, Feb., 109.
27 Distillers Co., Ltd. (Inventors : R. H. Hall, D. I. H. Jacobs and M. V. Jacquet). Froth Flotation Process. Brit. Pat. 717,927.
28 Badische Anilin- & Soda-Fabrik, A.G. Improvements in the Processing of Crude Copper Mattes. Brit. Pat. 710,827.
29 Norddeutsche Affinerie. Process for the Deoxidation of Copper and Copper Alloys. Brit. Pat. 719,196.
30 Sz^{a}ki, P. and Hegedüs, Z. Inclusions in Refined Cu of SnO_2. *Acta Tech. Acad. Sci. Hungar.*, 1952, **4**, 293. (In English).
31 Institute of Metals. Treatment of Swarf and Residues. Informal Discussion at Birmingham University. *Metal Industry*, 1955, **86**, Mar. 4th, 167.
32 Anon. Modern Reclamation of Non-Ferrous Metals, Parts 1–5. *Metal Bull.*, 1955, Mar. 25th, 15 ; Mar. 29th, 24 ; Apr. 7th, 17 ; Apr. 19th, 10 ; Apr. 22nd, 15.
33 British Productivity Council. A Review of Productivity in the Bronze and Brass Casting Industry. London, 1955.
34 Johnston, A. A Brass Foundry Incentive Scheme. *Metal Industry*, 1954, **85**, Oct. 22nd, 347 ; Oct. 29th, 368.
35 British Bronze and Brass Ingot Manufacturers Association. Ingots, Brass and Bronze. (Book). The Association, 1955.
36 American Foundrymen's Society. Melt Quality and Pressure Tightness of Copper-Base Alloys. The Society, 1955, 21 pp.
37 French, A. R. Melt-Quality Tests for Copper-Base Alloys. *Foundry Trade J.*, 1955, **98**, Mar. 10th, 253 ; Mar. 17th, 281.
38 Chalmers, B. Melting and Freezing. *J. Metals*, 1954, **6** (5), Sect. 1, May, 519 ; *Trans. A.I.M.E.*, 1954, **200**.

39 Pell-Walpole, W. T. Relationship Between Pouring Temperature, Porosity and Tensile Strength of Sand-Cast Bronze. *Foundry Trade J.*, 1955, **98**, Mar. 31st, 341.
40 Keller, K. and George, W. B. Vapor Holes from Loose Sand Grains in Brass and Bronze Castings. *Amer. Foundryman*, 1955, **27** (4), Apr., 40.
41 Cibula, A. Influence of Grain Size on the Structure, Pressure-Tightness and Tensile Properties of Sand-Cast Bronzes and Gunmetals. International Foundry Congress, London, June 20th-24th, 1955. Preprint No. 1121.
42 Schwietzke, G. Gas Porosity in Casting; Gassing and De-Gassing of Melts (of Aluminium Bronze). *Giesserei*, 1954, **41** (10), 254.
43 Hazelett, C. W. Continuous Cast Strip Offers Production Economies. *Materials and Methods*, 1955, **42** (1), July, 13.
44 Bremer, E. New Centrifugal Process Uses Sand-Resin Lining. *Foundry*, 1955, **83**, Aug., 90.
45 Sheepbridge Engineering Co., Ltd. Production of Long Centrifugal Castings, *The Engineer*, 1954, **197**, Apr. 16th, 583.
46 Canada Metal Co. Roto-Cast: A New Centrifugal Casting Process for Canada. *Canadian Metals*, 1954, **17**, July, 24.
47 Mohler, J. B. Centrifugal Casting of Sleeve Bearings. *Foundry*, 1954, **82**, Dec., 102.
48 Alfred Teves, K. G. Air-Cooled Engine Manufacture. *Foundry Trade J.*, 1954. **97** (1995), Nov. 25th, 637.
49 Barclay, T. M. Protective Coatings for Die Casting Dies. *Prod. Finish.* (London), 1955, **8**, Feb., 50.
50 Preston, T. E. W. Die Casting Technique for Bronze Chain. *Metalworking Prod.*, 1955, **99**, May 6th, 793.
51 Scholefield, H. H. European Vacuum Melting—History and Practice. *Metal Treatment*, 1955, **22** (115), Apr., 141.
52 Bishop, H. F., Layne, E. B. and Pellini, W. S. A Practical Method for Vacuum Degassing of Non-Ferrous Metals. *Foundry*, 1954, **82**, Dec., 78.
53 Rice J. L. Interim Report on the Shell-Moulding Process. Assocn. Bronze and Brass Founders, 1954; *Foundry Trade J.*, 1955, **98**, Jan. 6th, 10.
54 Taylor, D. A. Shell Moulding Materials: Their Testing and Properties. *British Cast Iron Research Association J. Res. & Dev.*, 1954, **5** (9), Dec., 502.
55 Turnbull, J. S. Developments in Lost Wax Precision Casting. *Machinist*, 1955, **99** (1), 1; *Proc. Inst. Mech. Eng.*, 1954.
56 Tipper, A. The CO_2 Process—Its Use in British Foundries. *Foundry*, 1955, **83**, June, 84.
57 Talbot, A. Cores and Moulds by the CO_2 Process. *Foundry Trade J.*, 1955, **98**, May 26th, 559; Disc., June, 2nd 599.
58 Atterton, D. V. Carbon-Dioxide Process. *Foundry Trade J.*, 1955, **98**, May 5th, 479; May 12th, 505.
59 Schumacher, W. How to Bake Cores Without Heat. *Modern Castings and American Foundryman*, 1955, **28**, July, 32.
60 Smith, R. M. and Grant, N. J. They're Making Molds Out of Glass Now. *Modern Castings and American Foundryman*, 1955, **28**, Aug., 30.
61 Vaders, E. New Copper Alloys Especially for Castings. *Z. Metallkunde*, 1954, **45**, Sept., 528.
62 McIntyre, J. B. British Practice in Producing Aluminium Bronze Castings. *Foundry*, 1955, Apr., 96.
63 Cook, M., Cowley, C. L. M. and Broadfield, B. R. The Use of Refractories in Low-Frequency Induction Furnaces for Melting Copper Alloys. *J. Inst. Metals*, 1955, **83** (6), Feb., 295.
64 Thews, R. E. Removal of Aluminium from Zinc Bearing Copper Alloys. *Giesserei*, 1954, **41** (21), 571.
65 Cirou, M. and Le Thomas, P. J. Desulphurization of Tin Bronzes by Sodium or Magnesium. *Fonderie*, 1954, Dec., 4281.
66 Portevin, A. and Pomey, J. Residual Stresses in Castings. Int. Foundry Congress, London, 1955; *Foundry Trade J.*, 1955, **99**, July 7th, 9.
67 Godtschalck, L. Contribution to the Study of the Stamping of Metals. *Metaux, Corrosion-Ind.*, 1955, **30**, Feb., 47; Mar., 110; Apr., 155. (In French).
68 Bovet, H. Hot Pressing of Leaded Nickel Silver. *Pro-Metal*, 1955, **7** (45), June, 516. (In French and German).
69 Wilkins & Mitchell, Ltd. Producing Cored Stampings on a Hot-Brass Press: Detachable Sub-Press Unit. *Engineering*, 1955, **179**, Apr. 1st, 417.
70 Kyle, R. E. The Closed-Die Forging Process. (Book), New York, Macmillan Company, 1954.
71 Properzi, I. Rolling of Metal Wires and Rods. Brit. Pat. 714,737.
72 Starkey, F. Guides and Strippers for Modern Rod and Bar Mills. *J. Iron & Steel Inst.*, 1955, **179** (1), Jan., 58.
73 Whitton, P. W. and Ford, H. Surface Friction and Lubrication in Cold Strip Rolling. *Inst. Mech. Eng.*, Preprint, Nov., 1954.
74 Colten, R. B. A Case Study: Applying Industrial Electronics to Thickness Measurement of Non-Ferrous Strip. *Gen. Mat. Engng.*, 1954, **1**, (8), Sept.-Oct., 12; *Motor Ind. Res. Assoc. Abstracts*, 1954, Dec., No. 7057.
75 Joint Metallurgical Societies Meeting in Europe, 1955. Problems of High Speed Wire-Drawing of Ferrous and Non-Ferrous Metals. *Wire Ind.*, 1955, **22**, July, 673–678, 696.
76 Christopherson, D. C. and Naylor, H. The Promotion of Fluid Lubrication in Wire-Drawing—I and II. *Wire Ind.*, 1955, **22**, Aug., 775; Sept., 885.
77 Robertson, W. H. A. & Co., Ltd. Robertson Driller Equipment for Copper Wire Sections. *Machinery*, 1955, **86**, April 8th, 758–759.
78 Stryker, W. L. Fabrication of Resistance Alloys. *Wire and Wire Prod.*, 1955, **30**, June, 668.
79 Maréchal, J. R. Investigations on a Rolling Defect in 67–33 Brass (Phantom Laminations). *Rev. Met.*, 1954, **51** (7), July, 441. (In French).
80 Turner, C. A. and Banno, S. P. Fine-Grained Brass for Deep Drawing. *Metal Progress*, 1955, **67** (3), Mar., 96.
81 Stickney, F. S. and Richards, J. T. Clean Beryllium Copper Strip Reduces Die Wear. *Metalworking Prod.*, 1955, **99**, Apr. 15th, 686.
82 Singer, A. R. E. Factors Affecting the Use of Hydraulic and Crank Presses for Cold-Working Operations. *Sheet Metal Ind.*, 1955, **32** (334), Feb., 85.
83 Yoder Company. High-Speed Welding of Non-Ferrous Tubing. *Welding J.*, 1953, **32** (11), Nov., 1098.
84 Olin Mathieson Chemical Corp. Forming Integral Tubing. *Metal Industry*, 1955, **86** (6), Feb. 11th, 105.
85 Imperial Chemical Industries, Ltd. Production of Copper Tubes. *The Engineer*, 1955, **200**, Sept. 23rd, 438.
86 Metalectric Furnaces, Ltd. Bright Annealing Copper Wire. *Metal Ind.*, 1955, **86**, May 13th, 399.
87 G. W. B. Furnaces, Ltd. Annealing Copper Tubes (Electrically). Furnaces Designed to Ease Maintenance Operation. *Elect. Times*, 1955, **128**, July 21st, 93.
88 Peterson, V. Better Copper Tubing Starts with Accurately Controlled Annealing. *Iron Age*, 1955, **175**, June 2nd, 87–89.

Two Ton Aluminium Hand Forgings

ALUMINIUM alloy hand forgings weighing as much as two tons will soon be in production from Harvey Aluminium's new forging facility. These massive hand forgings will be produced on huge hydraulic forging presses that Harvey is currently installing at the Torrance, California plant. The company believes that they will satisfy the most extended weight, dimensional, and metallurgical requirements anticipated by airframe and commercial manufacturers. In order to produce them, Harvey Aluminium is setting up a special operation in the ingot plant, and installing new direct chill casting equipment designed to cast ingots to a diameter 32 in. or more. Hand forgings are used as a source of readily available material from which parts can be machined for prototype and other development projects when the number of pieces required is small and the time available, or the uncertainty of design, makes it impracticable to construct forging dies.

Courses for Managers in Industry

THE UNIVERSITY OF CAMBRIDGE has arranged a fourth course for managers in industry. It will be held in Madingley Hall for a month—from 25th June to 21st July, 1956—and will be open to managers who have had some years of industrial experience and who are under 40 years old. The Secretary of the course is Mr. G. F. Hickson, M.A., and interested firms can obtain details from him at Stuart House, Cambridge.

The course will be concerned with problems which are common to all fields of management. A special study will be made of features of industrial society which must be taken into account in forming a policy for an individual firm. Problems of change will be treated as some of the most important that managers have to face. Three main topics for discussion have been proposed. They are: management and the changing structure of the national economy; human problems in industry; and Britain's international position. Lecturers from industry, from the University, and from elsewhere will provide the background.

The object of the course is to enlarge the outlook of managers, so that they can see their work (production, technical, sales, accounting, etc.) against the background of the firm as a whole, of the industry, the community, and the state. It is intended primarily for managers who appear likely to reach high levels; in consequence it should not be regarded as a school for teaching the techniques of efficient management, but rather as a short university course for those who are likely to become the industrial statesmen of the future. Admissions are limited to 40 and applications should be sent to the Secretary not later than March 31st.

Aston Chain's London Office

EXPANDING business has prompted the Aston Chain & Hook Co., Ltd., non-ferrous metal manufacturers, of Erdington, Birmingham, to establish a London branch office at 49 Conduit Street, W.1., with Mr. J. H. Randall as manager. This development is by agreement with E. C. Brown & Co., of 4 St. Mary Axe, who have acted as the Birmingham company's London agents for more than 50 years.

British Standards for Aluminium and its Alloys—The 1955 Revisions

By E. Elliott, A.Met., A.I.M.

Aluminium Development Association

A summary is given of the major changes involved in the recently published revisions of B.S. 1470–1477 and B.S. 1490, and some account of the reasons for them, together with a general note on the importance of keeping standards abreast of progress.

ALUMINIUM is now the second most important metal in the world's economy; in volume of production it exceeds that of all the other non-ferrous metals taken together. During the present century, output of aluminium has roughly doubled with each decade—a truly phenomenal rate of increase. Yet, before the last war, aluminium, while enjoying a varied field of application, was largely regarded as a material for special uses; the aircraft industry was the principal outlet for strong alloys, and indeed it was demand from that source more than any other that urged strong alloy development. Costs were high relative to other metals, and production was in the hands of fairly small units with equipment geared to small, rather specialised markets.

In that situation, the preparation of requirements governing quality, i.e., standard specifications, was not pursued with any urgency, except by the aircraft industry, where high and consistent quality was, and is, vital. Before the war, standardisation generally was not accepted so readily as it is to-day, and supply of special batches of material to specifications laid down by the purchaser was much more common than is economically possible in the high-rate production industries of the second half of the 20th century. Few general engineering standards were therefore prepared for aluminium and its alloys, in wrought or cast form, and the principal documents governing quality were therefore aircraft materials, normally the British Standard L series and the D.T.D. series of the Air Ministry, these last now being in the hands of the Ministry of Supply. (It is often not realised that D.T.D. specifications are tentative, the aim being that the materials they cover shall become the subject of a B.S.L. standard when they are proved satisfactory; the seeming tardiness with which this is sometimes done has led to many D.T.D. specifications being regarded as permanent). Any grade of aluminium or aluminium alloy sold to a B.S.L. standard or a D.T.D. specification is subject to the inspection requirements of B.S.L100 or B.S.L101, according to whether it is wrought or cast, and these requirements are high. It is therefore unfortunate that both L. and D.T.D. numbers are much misused; they are applied to alloys which are not inspected to aircraft requirements, and, particularly with castings, sometimes even to alloys of no controlled composition or quality at all. Fortunately this is a diminishing tendency, and such misapplication of designations is only perpetrated by the uninformed, now that correct nomenclature is well established as will appear below.

TABLE I.—TITLES OF BRITISH STANDARDS 1470–1477 and 1490—ORIGINAL AND REVISED VERSIONS

British Standards	Original (1948–51)	Revised (1955)
1470	Sheet and Strip	Sheet and Strip
1471	Tubes	Drawn Tube
1472	Forgings	Forgings and Forging Stock
1473	Wire for Rivets	Rivet, Bolt and Screw Stock for Forging
1474	Welding Wire	Extruded Round Tube and Hollow Sections
1475	Wire for General Purposes	Wire
1476	Bars, Rods and Sections	Bars, Rods and Sections
1477	Plate	Plate
1490	Ingots and Castings	Ingots and Castings

The consumption of aluminium in this country is over five times that of pre-war days, and the great bulk of the increase has been in non-specialised applications. Thus, the aircraft industry now receives less than a fifth of the output, while such industries as road and rail transport, shipbuilding, building and structural engineering, electrical engineering, packaging, and the food and chemical industries are using increasing quantities of the metal. To cope with this demand, the great increases in facilities for semi-fabrication made during the war have been augmented by equally spectacular post-war installations. Towards the end of the war, concerned with the ability of the industry of this country to sell for civil use the output of its expanded production facilities, aluminium technologists realised the importance of preparing standards for aluminium and its alloys for general engineering applications, since those then available were totally inadequate.

In tune with the times, the first effort at a logical series of standards was made under the auspices of the Ministry of Supply, and on behalf of that body the British Standards Institution published in 1945 the STA/7 Group 6 series, which covered the composition and mechanical properties of four grades of pure aluminium, 15 wrought and 15 casting alloys, in a number of conditions of temper and heat-treatment. This series was intended for the purchasing of material for service requirements other than aircraft, and it fulfilled a useful purpose during the difficult period of transition from war to peace production. It established the principle of a series of numbers to identify alloys, with strength broadly increasing through the series, but its temper and heat-treatment nomenclature was unsystematic, and it has now been replaced, even for service use, by the British Standards for Aluminium and its Alloys for General Engineering Purposes.

These standards were first published during the years 1948–51. Their titles, as then applied, appear, together with their titles as revised in 1955, in Table I. They were produced by two Technical Committees of the British Standards Institution, one dealing with B.S.1490 for ingots and castings, and another with B.S.1470–1477 for the various wrought forms, namely the NFE/18 and NFE/19 Committees. On these committees are represented the manufacturers of pure aluminium ingots, the producers of alloy ingots for remelting, and the principal users of semi-fabricated products in aluminium and its alloys, including both industrial concerns and Government Departments. There are also representatives of the relevant professional and technical institutions, and of the research and development associations. On the NFE 18 Committee the producers of castings in the three main categories, namely, sand, gravity and pressure die are represented, while on the NFE/19 Committee are the makers of sheet and strip, tubes, bars, forgings, wire and the other wrought forms. Much work, both inside and outside committee, was done before the various standards reached the stage where a draft, agreed by the committee members, could be circulated to industry for comment. This is a most important stage in the preparation of standards; copies of the draft are sent in large numbers throughout the industry of Great Britain, wherever there might be an interest in aluminium and its alloys, and also throughout the Commonwealth and to certain other oversea countries. A reasonable period is allowed for the receipt of comments, which must all be reviewed and resolved, before the standard can be published. By this means, standards represent the agreed views of a very wide section of industry, and B.S.1490 and B.S.1470–1477 were generally approved and welcomed upon issue, and have proved invaluable to the correct application of both wrought and cast aluminium and its alloys, and to developments in their use.

Post-war development in all industry has been rapid, but in few branches has it been so noteworthy as in the production and application of aluminium and its alloys. Standards that fall behind change in the materials they govern are rapidly made anachronistic and fall into desuetude. While the most spectacular changes may be the introduction of fresh alloy compositions, many other factors must be taken note of; changes in temper, form, heat-treated condition, sizes, tolerances on dimensions, methods of test—all must affect standard specifications. During the first few years after the issue of standards, they may be maintained by the circulation, when necessary, of amendment slips covering specific changes, and this policy was pursued with B.S.1470–1477 and B.S.1490, but eventually it becomes essential for a completely new version to be prepared, and this was done for these standards in 1955. The method of preparation of revised standards is the same as that for new ones, which has briefly been described above; the new documents therefore represent the views of producers, users Government Departments, and independent technical bodies. Much work was done by the aluminium industry before its recommendations were put to the B.S.I., and the work of the Technical Committees was correspondingly simplified.

Some account will now be given of the revised standards, attention being drawn particularly to the important changes that have been made, as compared with the original versions.

General

Some of these alterations are common to all the standards; thus, there have been alterations in layout and style, in accordance with the recommendations of a B.S.I. committee which has prepared a document, not yet published, governing these factors in non-ferrous specifications. The general clauses of B.S.1470–1477 and 1490 dealing with such matters as selection of test samples, methods of test, certificate of compliance, etc., now precede the specific clauses concerned with composition, mechanical properties, etc., for individual materials—a convenient reversal of order. Each standard now has a "Scope" clause, summarising clearly just what is covered by it, while the Foreword gives reasons for the changes made in the 1955 revision.

Since B.S.1470–1477 and 1490 first appeared, the B.S.I. has published B.S.1957 "Presentation of numerical values (fineness of expression; rounding of numbers)." This includes a "rounding rule" for numerical values, and it has been applied to the limits of composition and mechanical properties in the standards, but not to dimensional tolerances. Under this rule, the determined values are "rounded" to the last place of figures stated as limits, as in the following examples:—

Specification		Extreme Values which Round to Specification Limits	
min.	max.	min.	max.
—	0·050	—	0·0505
0·2	0·6	0·15	0·65
6	9	5·5	9·4
6·0	9·0	5·95	9·05
7	10	6·6	10·5
7·5	10·5	7·46	10·54

It should be mentioned that a similar system had already been applied to B.S.1490 : 1949, but not in the case of B.S.1470–1477; the practice is now regularised with all the standards by reference to B.S. 1957. Other standards to which reference is now made include B.S.1499 "Sampling Non-Ferrous Metals," for sampling for independent tests, and B.S.1728 "Methods for the Analysis of Aluminium and Aluminium Alloys," for referee analysis where the appropriate method has been published.

Metric equivalents of proof stress and tensile strength values have been included where appropriate, for information only. Also as a result of international agreement the term "tensile strength" has been substituted for "ultimate tensile stress." Where applicable, elongations may be determined on a gauge length of $4\sqrt{A}$ as an alternative to 2 in.

B.S.1490 still includes a summary table of approximate compositions, together with specified properties and related current aircraft specifications. To it has been added a column indicating, for information only, the type of casting—sand, gravity or pressure die—for which the alloy is most commonly used. In B.S.1470–1477, references to related specifications are no longer included, but each standard now has a summary table of all compositions of pure aluminium and alloys in the series, with an indication of which of these is covered by the particular document.

The definition of heat-treatment batch in the series B.S.1470–1477 has been modified to fall in with modern production methods. More detail is given in the appendix on determination of proof stress, and the appendix, for information only, on heat-treatment and annealing has been amended and included in all the series B.S.1470–1477.

B.S. 1490 : 1955—Aluminium and Aluminium Alloy Ingots and Castings for General Engineering Purposes

One of the most important effects of seven years' experience of the aluminium standards has been the firm establishment within both producing and using industries of the system of nomenclature that they embody, enabling easy reference to be made to any grade of pure aluminium or aluminium alloy together with its form and condition. There are no alterations to the designations of casting alloys in B.S.1490 : 1955. The alloys are numbered consecutively, with the numeral 0 for pure aluminium ingots for remelting. Prefix letters LM (standing for "Light Metal") are common to all, and the absence of suffix letters indicates the ingot form, while for castings they have the following meanings :—

M As cast.

W Solution-treated.

P Precipitation-treated.

WP Solution- and precipitation-treated, i.e., fully heat-treated.

WP (special). Fully heat-treated and subsequently stabilised (applicable to certain piston alloys).

No special designation is devoted to the stress-relieved condition, the procedure for this, when necessary, being left to agreement between supplier and purchaser.

The principal qualities standardised in B.S.1490 are chemical composition and the mechanical properties which must be attained on separately cast test bars ; these requirements apply to both ingots and castings, except that no mechanical properties are specified for LM0, pure aluminium ingots. It is important here to emphasise that these mechanical properties are measured to ensure that the metal is in a satisfactory condition when poured into ingots or castings ; it must not be assumed that they will be attained in all parts of all castings. Furthermore, pressure die castings may often have somewhat better strength and elongation than those of the chill cast test bars representing them.

Table II lists the alloys covered by B.S.1490 : 1955, together with their composition as castings and properties on test bars. It will be seen immediately that LM17 and LM19 have been omitted ; also, four new alloys have been added, namely LM21, 22, 23 and 24. The deletion of LM17 and LM19 is in accordance with the policy in standardisation of not including materials which are no longer in general use. LM17 was an aluminium–12% silicon–3% nickel alloy used as cast, and LM19 an aluminium–3% copper–1% magnesium–1¼% cadmium alloy used solution-treated ; neither of these alloys has maintained its place in the modern foundry as a general engineering material. The characteristics of the four newly standardised alloys are summarised below.

Individual Alloys

LM21

The most famous of the twenty alloys in B.S.1490 : 1949 was undoubtedly LM4, the alloy originally developed to be made from high strength wrought alloy aircraft scrap of the aluminium-copper-magnesium type, and well-known for aircraft applications as D.T.D.424. It has been estimated that this alloy accounts for over 40% of the aluminium alloy castings made in this country, and similar compositions are in use in many oversea countries. It was research into alloy LM4 and other alloys, made largely from scrap, that clearly showed that the pre-war prejudice against so-called "secondary" alloys was quite without foundation. If alloys are made to specified composition, it matters not whether they originate from scrap or virgin ingot, their qualities will be the same ; as an example of this, the work of Lees and Glaisher[1] may be cited.

Alloy LM4 is continued virtually unchanged in B.S.1490 : 1955 ; it has a top limit on zinc content in castings of 0·5%. The last part of the war saw the entry into service aircraft of the high strength aluminium-zinc-magnesium-copper wrought alloys (D.T.D.363, 683 and 687), and their use has increased very considerably since then, with the effect that the proportion of zinc-bearing scrap from aircraft sources has increased, to present difficulties as a source of raw material for the manufacture of LM4. As a result, ingots of LM4-type alloy began to be offered with fairly high zinc content. Such practice is always fraught with some danger, since, while reputable ingot suppliers might make such non-standard ingots to their own internally controlled composition, and explain to their customers the material's properties, others might seize the opportunity to supply unsatisfactory compositions. Thus, although, as mentioned below, increased proportions of zinc have no deleterious effect on alloy LM4, other elements must not be uncontrolled if the mechanical properties are to be maintained ; Scheuer, Williams and Wood[2] have shown the importance of control of magnesium and of copper if the specified elongation is to be attained.

True to their constant policy of quality control, the organised founders, through the Light Metal Founders' Association, and the technical body representing the principal ingot manufacturers, ALAR, Ltd., arranged for exhaustive tests[3, 4] of the effect of zinc on alloys of LM4 composition, which showed that the composition finally selected and standardised as LM21 (allowing up to 2·0% zinc) was comparable with LM4 as to castability, mechanical properties and corrosion resistance.

The uses of LM21 are the same as those of LM4, except that it is not at present listed as a pressure die casting alloy. It is a general-purpose, medium-strength alloy of moderate ductility, good castability, good machinability, and corrosion resistance when unprotected which is adequate for all but severe exposures. Its history is a good example of collaborative work resulting in a standard specification.

LM22

This alloy is yet another development of that versatile light alloy LM4. Although that material has often been solution-treated or fully heat-treated to improve its strength and hardness, the heat-treated forms have never been standardised, chiefly because the response of the alloy to heat-treatment has been variable. Nevertheless, it was realised that an alloy of this type could, under optimum condition, offer very good strength and ductility when solution treated, and by setting closer limits on copper and keeping the magnesium below 0·05%, these properties are ensured in alloy LM22-W, used as gravity die castings. The contents of other impurities such as nickel, lead, etc., are also lower than in LM4. This alloy should enjoy a considerable volume of use for castings which, without demanding specialised foundry technique, have to withstand fairly high stresses or a measure of impact loading.

TABLE II.—COMPOSITION AND MECHANICAL PROPERTIES OF THE ALUMINIUM ALLOYS LISTED IN B.S. 1490 : 1955

Alloy No.	Specified Compositions as Castings (unless a range is given, all figures are maxima)											Condition	Specified Properties		
	Al%	Cu %	Mg %	Si %	Fe %	Mn %	Ni %	Zn %	Pb %	Sn %	Ti %	S = sand cast C = chill cast	Tensile Strength (tons/sq. in.)	Elongation (% on 2 in.)	Brinell Hardness
LM1 ..	Remainder	6–8	0·15	2–4	1·0	0·6	0·5	2–4	0·3	0·2	—	M S	8·0	—	—
												M C	10·0	—	—
LM2 ..	Remainder	0·7–2·5	0·03	9·0–11·5	1·0	0·5	1·0	1·2	0·3	0·2	0·2	M S	8·0	—	—
												M C	9·5	—	—
LM3 ..	Remainder	2·5–4·5	0·10	1·3	1·0	0·5	0·5	9–13	0·3	0·2	—	M S	9·0	—	—
												M C	—	—	—
LM4 ..	Remainder	2·0–4·0	0·15	4·0–6·0	0·8	0·3–0·7	0·3	0·5	0·1	0·05	0·2	M S	9·0	2	—
												M C	10·0	2	—
LM5 ..	Remainder	0·1	3·0–6·0	0·3	0·6	0·3–0·7	0·1	0·1	0·05	0·05	0·2 (incl. Nb)	M S	9·0	3	—
												M C	11·0	5	—
LM6 ..	Remainder	0·1	0·10	10·0–13·0	0·6	0·5	0·1	0·1	0·1	0·05	—	M S	10·5	5	—
												M C	12·0	7	—
LM7 ..	Remainder	1·0–2·5	0·05–0·20	1·5–3·5	0·3–1·4	0·1	0·5–1·7	0·1	0·05	0·05	0·05–0·30 (incl. Nb)	M S	9·0	2	—
												M C	10·0	2	—
LM8 ..	Remainder	0·1	0·3–0·8	5·5–6·0	0·6	0·5	0·1	0·1	0·1	0·05	0·2 (incl. Nb)	M S	8·0	2	—
												M C	10·5	3	—
												P S	9·5	1	—
												P C	12·0	2	—
												W S	10·5	2·5	—
												W C	15·0	5	—
												WP S	15·0	—	—
												WP C	18·0	2	—
LM9 ..	Remainder	0·1	0·2–0·6	10·0–13·0	0·6	0·3–0·7	0·1	0·1	0·1	0·05	0·2 (incl. Nb)	P S	11·0	1·5	—
												P C	15·0	2	—
												WP S	15·5	—	—
												WP C	19·0	—	—
LM10 ..	Remainder	0·1	9·5–11·0	0·25	0·35	0·10	0·10	0·10	0·05	0·05	0·2 (incl. Nb)	W S	18·0	8	—
												W C	20·0	12	—
LM11 ..	Remainder	4·0–5·0	0·10	0·25	0·25	0·10	0·10	0·10	0·05	0·05	0·05–0·30 (incl. Nb)	W S	14·0	7	—
												W C	17·0	13	—
												WP S	18·0	4	—
												WP C	20·0	9	—
LM12 ..	Remainder	9·0–10·5	0·15–0·35	2·0	0·5–1·5	0·6	0·5	0·1	0·1	0·1	—	WP	—	—	100–150
LM13 ..	Remainder	0·5–1·3	0·8–1·5	11·0–13·0	0·8	0·5	2·0–3·0	0·1	0·1	0·1	0·2 (incl. Nb)	WP S	11·0	—	100–150
												WP C	16·0	—	
												WP S Special	9·0	—	65–85
												WP C Special	13·0	—	65–85
LM14 ..	Remainder	3·5–4·5	1·2–1·7	0·6	0·6	0·6	1·8–2·3	0·1	0·05	0·05	0·2	WP S	14·0	—	100–130
												WP C	18·0	—	
												WP S Special	12·0	—	75–85
												WP C Special	15·0	—	75–85
LM15 ..	Remainder	1·3–3·0	0·5–1·7	0·6–2·0	0·8–1·4	0·1	0·5–2·0	0·1	0·05	0·05	0·05–0·30 (incl. Nb)	WP S	18·0	—	100–150
												WP C	21·0	—	
LM16 ..	Remainder	1·0–1·5	0·4–0·6	4·5–5·5	0·6	0·5	0·25	0·1	0·05	0·05	—	W S	11·0	2	—
												W C	13·0	3	—
												WP S	15·0	—	—
												WP C	17·0	—	—
LM18 ..	Remainder	0·1	0·10	4·5–6·0	0·6	0·5	0·1	0·1	0·1	0·05	0·2 (incl. Nb)	M S	7·5	3	—
												M C	9·0	4	—
LM20 ..	Remainder	0·4	0·15	10·0–13·0	0·7	0·5	0·1	0·2	0·1	0·05	0·2	M S	10·5	3·5	—
												M C	12·0	5	—
LM21 ..	Remainder	2·0–4·0	0·15	4·0–6·0	0·8	0·3–0·7	0·3	2·0	0·1	0·05	0·2	M S	9·0	1·5	—
												M C	10·0	1·5	—
LM22 ..	Remainder	2·8–3·8	0·05	4·0–6·0	0·7	0·3–0·6	0·15	0·15	0·05	0·05	0·2 (incl. Nb)	W S	—	—	—
												W C	16·0	8	—
LM23 ..	Remainder	0·8–2·0	0·05–0·20	1·5–2·8	0·8–1·4	0·1	0·8–1·7	0·1	0·05	0·05	0·05–0·30 (incl. Nb)	P S	10·0	2	—
												P C	12·5	3	—
LM24 ..	Remainder	3·0–4·0	0·1	7·5–9·5	1·3	0·5	0·5	1·0	0·3	0·2	—	M S	—	—	—
												M C	11·5	1·5	—

LM23

The development of alloy LM23 is an example of the difficulties faced by the technologist, anxious to simplify his production and reduce the number of alloys in use, but nevertheless unable to ignore well-established views. Alloy LM7 in B.S.1490 : 1949 was covered as-cast and also as precipitation-treated, but many castings bought in the precipitation-treated condition were actually made to a tighter compositional specification, with a view to securing better properties, particularly at elevated temperatures. This has been recognised in B.S.1490 : 1955, where LM7-M is retained, but the precipitation-treated version has become LM23-P, with closer limits on the alloying elements copper, silicon, iron and nickel.

TABLE III.—GENERAL GUIDE TO THE SELECTION OF CASTING ALLOYS

B.S. 1490	Casting Characteristics†					General Properties		
	Suitability for							
	Sand Casting	Gravity Die Casting	Pressure Die Casting	Fluidity	Resistance to Hot-Tearing	Resistance to Corrosion	Machinability	Pressure Tightness
LM1	F	G*	F	F	F	P	G	F
LM2	G	G	G*	G	G	G	F	G
LM3	G*	U	U	F	P	P	G	P
LM4	G*	G*	G*	G	G	G	G	V
LM5	F*	F*	F	F	F	V	G	P
LM6	V*	V*	G*	V	V	V	F	V
LM7	G*	G*	F	F	G	G	G	G
LM8	G*	G*	U	G	G	V	F	G
LM9	V*	V*	U	V	V	V	F	V
LM10	F*	F*	U	F	G	V	G	P
LM11	F*	F*	U	F	P	F	G	P
LM16	G*	G*	U	G	G	G	G	G
LM18	G*	G*	G	G	G	V	F	G
LM20	V	V*	G*	V	V	G	F	V
LM21	G*	G*	G	G	G	G	G	V
LM22	G	G*	U	G	G	G	G	V
LM23	G*	G*	U	F	G	G	G	G
LM24	F	F	V*	G	G	G	F	G
ALLOYS FOR USE AT ELEVATED TEMPERATURES								
LM12	F	G	U	F	G	P	V	F
LM13	G	G	U	G	V	G	F	F
LM14	F*	G*	U	G	G	F	G	F
LM15	F*	G*	U	F	G	G	G	F

V = Very good. G = Good. F = Fair. P = Poor. U = Unsuitable.

* Form in which, according to B.S.1490 : 1955, the alloy is most commonly used.

† The classification of suitability for a particular casting process (columns 2, 3 and 4) depends to some extent on the size and complexity of the casting. Also the satisfactory casting of certain alloys requires a specialised foundry technique. A rather low rating has been given in such cases, since the founder will encounter difficulties when casting these alloys for the first time. Alloys included in this category are Nos. 5, 10, 11 and, to a lesser degree, 14.

LM24

Hitherto in this country, the principal alloy used for pressure die castings has been LM2-M, the aluminium-10% silicon–1½% copper alloy. It has now been joined by alloy LM24-M, a material already known to founders here under the designation S.A.E.306, as used in the United States. The properties offered by this aluminium–8½% silicon–3½% copper alloy on chill cast test bars may not seem particularly impressive, minimum values being 11½ tons/sq. in. tensile strength and 1½% elongation, but it must be noted that according to specification S.A.E.306, the values obtained on pressure die cast test pieces should be approximately 18 tons/sq. in. tensile strength and 3% elongation. Increasing use of this alloy by pressure die casters can be expected. Incidentally, some readers may complain that the specification gives no indication that LM24-M offers such good mechanical properties; the fact remains, however, that it is the function of standards to safeguard quality, not to give information. That is the task of the founders, development associations and other technical bodies.

While the outstanding changes in B.S.1490 : 1955 are certainly the addition of new alloys, other important points must be noted. Alloy LM8, aluminium–5% silicon–½% magnesium, is versatile in that it may be used as-cast or in a variety of heat-treatments; this has been recognised by the addition to W and WP of the M and P conditions, so that this alloy now offers a range of mechanical properties according to how it is treated after casting. The earliest high strength aluminium casting alloy, well known as Y alloy and LM14 in B.S.1490, has been discontinued in the as-cast M condition, but retained heat-treated WP and WP (special). Minor changes in composition have been made; for instance, the high strength alloys LM10 and LM11 have been more closely defined by the insertion of limits on certain impurities, which were assumed in B.S.1490 : 1949. Table III gives a guide to the selection of casting alloys, covering all the materials in B.S.1490. It must not, of course, be regarded as absolute, and consultation between founder and user at an early stage of casting design is always desirable and often imperative.

(To be concluded)

REFERENCES

1 Lees, D. C. G. and Glaisher, W. H., "The Aluminium Casting Alloy D.T.D. 424 (now known as LM4)," *Metallurgia*, 1951, **43**, 73–82.

2 Scheuer, E., Williams, S. J. and Wood, J., "The Effect of Copper, Silicon and Magnesium on the Mechanical Properties of Aluminium Alloys of the D.T.D.424 Type," *J. Inst. Met.*, 1951, **79**, 57–72.

3 Smith, F. H., "The Effect of Zinc in Aluminium-Silicon-Copper Casting Alloys," *Metallurgia*, 1955, **51**, 24–28.

4 Anon., "Some Effects of Variation in the Zinc Content on the Mechanical Properties and Corrosion Resistance of Al-Si-Cu Alloys," *ibid.*, 115–119.

Engineering News Letter

BEGINNING this month, a semi-monthly newsletter with the title of *European Engineering News Report*, is being published by Vision, Inc., one of the largest international publishers in the United States, and sold on a subscription basis to American industrialists. The new publication will be edited by Fritz Hirschfeld, graduate mechanical engineer from the Polytechnic Institute of Brooklyn, New York, who is European editor of *Consulting Engineer*. It will carry no advertising, represent no special interests, and endeavour to report objectively and independently on all the legitimate engineering information of potential use to its subscribers. *European Engineering News Report* will not be a digest of articles appearing in European publications, but an evaluation of material gathered primarily through direct contacts made by Mr. Hirschfeld and his staff, who will welcome the opportunity to visit British manufacturers and engineers. He may be reached at his European address: Spanweidstrasse 3, Zurich, 6, Switzerland.

New Pipe Plant

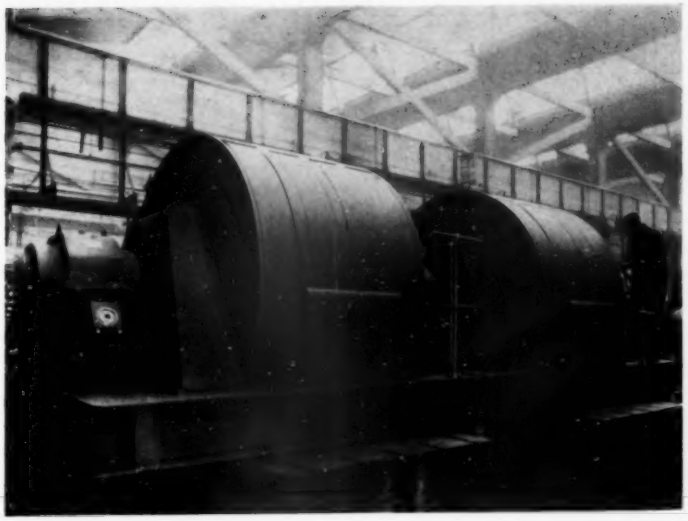
CLAIMED to be the only one of its kind in the United Kingdom and Western Europe capable of manufacturing steel pipes to the length and diameter required to meet increasing world demand, a new plant at the works of the South Durham Steel and Iron Co., Ltd., has recently gone into production. It is equipped with four Lincolnweld automatic machines for internal welding by the automatic submerged-arc process, and with three Lincolnweld twin-arc fully automatic machines fitted with twin feeds for the electrodes, for automatic submerged arc external welding. X-ray inspection is carried out at each stage of pipe manufacture. One of the first contracts secured is for 75,000 tons of special pipe for transmitting natural gas over a distance of 250 miles in Canada.

Heat Treatment Practice Conference

THE Metallurgy (General) Division of the British Iron and Steel Research Association is organising a conference on heat treatment practice, to be held at Ashorne Hill, Leamington Spa, on June 5th and 6th next. Emphasis will be given to the consideration of practical problems connected with the heat treatment of steel products, from small engineering components to large forgings.

Electrical Plant for the Metal Industries

Progress in 1955 Reported



Courtesy of The British Thomson-Houston Co., Ltd.

Double-unit D.C. motor with modern "streamline" construction on test at Rugby Works. Rated at 4,000 h.p., this motor is for Lysaghts Works Pty., Ltd., Australia.

THE electrical industry continues to play a major part in the provision of equipment for the metallurgical and metal-using industries. Electrical drives for rolling mills—whether as new construction or for the modernisation of existing mills—undoubtedly constitute one of the outstanding applications of electricity in this field, but a considerable volume of business concerns the smaller motors, switchgear, and, more recently, electronic control equipment. The following information, based on surveys of the activities of a number of the large electrical engineering concerns in 1955, will give some idea of the extent to which metal working depends on electricity. The review is not exhaustive, and such items as electric furnaces for heat treatment are no more than mentioned in view of the review of developments in that field which we hope to publish later in the year.

The British Thomson-Houston Co. Ltd.

Rolling Mills

The past year has seen the starting up of a number of rolling mills with B.T.H. drives, including two of the largest mills in Australia. One is a 66 in. 6-stand hot strip mill at Australian Iron and Steel Ltd.'s Port Kembla Works, and the other the 56 in. 4-stand tandem cold strip mill of Lysaght's Works Proprietary, Ltd., also at Port Kembla. The latter is driven by one 2,000 h.p. and three 4,000 h.p. stand motors and a 1,000 h.p. reel motor. These are all special low inertia D.C. motors, and are to be supplied from two 6,000-kW synchronous motor-generator sets.

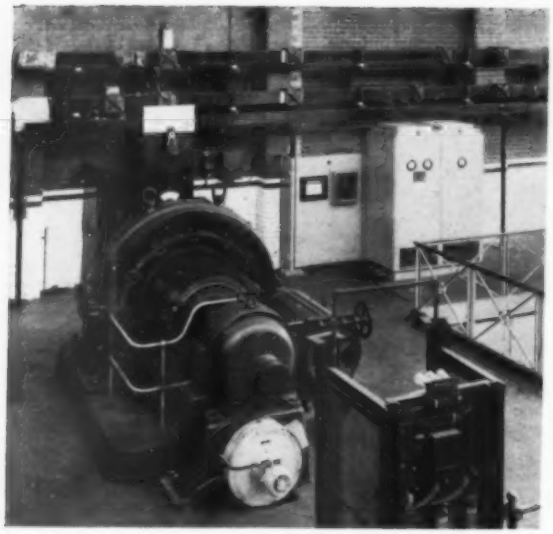
Also commissioned during the year was an 18 in. 3-high merchant mill at Shelton Iron Steel & Coal Co., Ltd., Stoke-on-Trent. The drive is a 1,500 h.p., 742 r.p.m., 5,500 volt slipring induction motor, and the control gear includes high tension stator contactors with "plugging" control to give quick stopping and also slip regulation by means of contactors and resistances in the rotor circuit.

Three large installations are due to be started up early this year—a drive for a 12 in. continuous merchant mill for Kwinana, Western Australia; a drive for a rotary forge mill for large seamless tubes at Stewarts & Lloyds' Clydesdale Works; and a drive for a 5-stand tandem cold tinplate strip mill for the Velindre Works of the Steel Company of Wales. The tube mill drive comprises two 2,200 h.p. 55/115 r.p.m. D.C. motors with synchronous motor generator set for driving gap-roll mills, and two 3,000 h.p., 500 r.p.m., 11,000 volt synchronous motors for driving elongators. At Velindre, the installation is similar to that in operation at Trostre and the B.T.H. equipment comprises one 1,750 h.p., two 3,500 h.p., one 4,000 h.p., one 5,500 h.p. and one 900 h.p. low inertia D.C. motors, together with two synchronous motor generator sets and control gear. The control gear embodies the latest combination of amplidynes and magnestats (magnetic amplifiers).

Among the orders placed during the year is one for a reversing drive for the 43 in. cogging mill at Steel, Peech & Tozer. With a 7,000 h.p., 50/100 r.p.m. motor supplied from a flywheel motor-generator set, this will be one of the largest cogging mill drives in the country. From Australia has come an order for the Broken Hill Proprietary Co's. 18 in. continuous strip and skelp mill, comprising 14 D.C. motors ranging from 250 h.p. up to 1,000 h.p. They will be supplied from two 3,500 kW banks of mercury arc rectifiers, each bank consisting of eight Type MB6/16 tanks. The order also includes switchgear and control gear.

Firth Vickers Stainless Steels, Ltd., have ordered drives for the roughing and finishing stands of a 3-high alloy bar mill, and for a double duo mill, and a drive for a reversing cold mill is being supplied to Northern Aluminium Co., Ltd., at Banbury. The last-named includes a 1,800 h.p. motor with synchronous motor-generator for the main drive, together with a number of auxiliary motors and the complete control gear.

Several large orders have been received for process line equipment. One for Velindre covers line drives,



Courtesy of The British Thomson-Houston Co., Ltd.

1,000 kW. 255 V. germanium power rectifier installed in a works of the General Chemical Division of Imperial Chemical Industries, Ltd. The rectifier cubicles on the right replace the rotary convertor shown in the foreground.

four motor-generator sets, and loop control for a 700 ft./min. continuous tinplate annealing and cleaning line. Others concern modifications to 18 hot dip tinning lines and to a 340 ft./min. slitting and shearing line at Ebbw Vale.

Rectifiers

There has recently been much speculation as to whether the multi-anode air-cooled pumpless mercury arc rectifier, in the production of which this country is at present supreme, could be applied to the exceptionally large installations needed for the production of aluminium. It was therefore an event of unusual interest when, early in 1955, the great French chemical combine, Societe Pechiney, decided, after much investigation, to use this type of rectifier entirely for the new aluminium plant in the French Cameroons. This single pot line will have a rating of 95,000 amp. at 1,100 volts, the largest in the world ; but the special protective schemes originated by B.T.H. for their recent electro-chemical rectifier installations had provided the means for using pumpless rectifiers even in such very large stations. B.T.H. received an order for 78 pumpless tanks, the balance, together with transformers, switchgear, etc., being supplied by Societe Alsthom, the main contractors.

Orders for mercury arc rectifiers include two 3,500 kW. units for Broken Hill's hot strip mill, the installation to be similar in many respects to that at Abbey Works. Among smaller installations ordered are two 1,320 kW. units for Lysaghts Works Pty., Ltd., Australia ; two, of 800 kW. and 400 kW., respectively, for Firth-Vickers Stainless Steels, Ltd. ; nine 265 kW. 240 V. rectifiers for Australian Iron & Steel, Ltd. ; and four equipments, two of 1,200 kW. and two of 1,500 kW. for Dorman Long (Steel), Ltd.

During the year, the first B.T.H. germanium power rectifier was commissioned in a works of the General Chemical Division of I.C.I. Rated at 1,000 kW., 225 volt, 3,920 amp., it is operating in parallel with rotary converters on electrolytic duty which involves long periods of continuous operation at full load. The rectifier gives the extraordinarily high output of 7·4 kW./cu. ft. of volume, or 55·5 kW./sq. ft. of floor space.

Furnace Equipment

Further expansion plans for the steel industry in this country and the Commonwealth have been reflected in a steady flow of orders for Birlec arc furnaces, for which B.T.H. is supplying the electrode position amplidyne control regulators—and in many cases the furnace transformers and tap changers as well. The operation of the electro-hydraulic control system on the 7,500 kVA. furnaces commissioned at the works of Ferrometals, Ltd., during the year has given satisfaction, and an enquiry has been made for a third furnace with similar control. Following a year's satisfactory operation of the 60 ton furnace at Samuel Fox & Co., Ltd., a further furnace is to be installed, and negotiations are proceeding for similar and larger furances for the steel industry, in which B.T.H. automatic electrode amplidyne control is being put forward, together with B.T.H. furnace transformers up to 20 MVA.

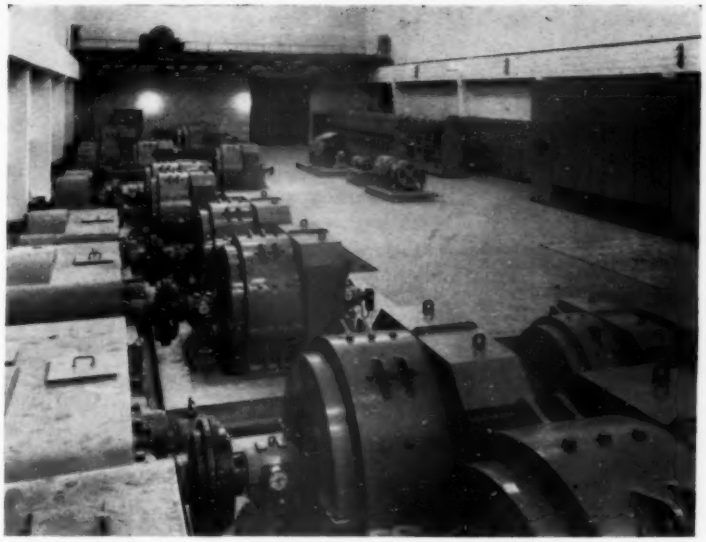
During the year, 600 kW. 1 kc./s. substation equipment for high frequency melting was commissioned at K. & L. Steelfounders, Ltd., for which B.T.H. supplied a 0·9 power factor synchronous motor-alternator set, together with reactor starting gear. The method of excitation ensures the rapid voltage recovery after load changes which is particularly desirable for induction heating applications. Development of the 10 kW. 10 kc./s. heteropolar alternator has been successfully completed, and the first set has been installed at Cranfield Aeronautical College. It is expected that this set will be particularly suitable for educational establishments, and that it will provide a preferable alternative to more costly methods of supplying power for such applications as H.F. brazing.

The most important resistance furnace order covers switchboards and cubicles housing control circuits and contactors for supplying some 3,500 amp. of heating circuits for each of three batteries of furnaces for annealing electrical quality silicon steel. B.T.H. is also providing equipment for the control of a 1,500 kW. decarburising furnace in one of the process lines for the same scheme.

Industrial Electronics

Welding Controls—Development on welding controls has been mainly directed towards extending the application of the dekatron counter type of control. A synchronous welding control equipment has been developed using three dekatrons, two of which control the timing and the third an operation sequence. This principle allows up to nine different 'operations' to be selected. The control is designed with the requirements of the motor industry in mind, and the ingitrons are fitted with thermostat safety switches, thus enabling the usual water flow pressure switch to be eliminated. A spot-welding control panel of the synchronous type with heat control has been designed using dekatron timing. This has a wide range, and is capable of giving a spot weld of 1–90 cycles duration, as compared with the 1–30 cycles for the control it supersedes.

Magnestat Mill Control—Complete control of motor speed, strip tension, etc., in the new 5,000 ft./min.,



Some of the 7,850 h.p. of motors and control equipment for driving a 17 stand merchant mill at A/S Norsk Jernwerk, Mo-i-Rana, Norway. English Electric also supplied more than 6,000 h.p. of drives and control for the auxiliaries of the blooming mill at this works.

Courtesy of The English Electric Co., Ltd.

5-stand cold strip mill at Velindre will be effected by the use of magnetic amplifiers instead of the amplidynes used hitherto in similar installations. The drive to each stand is essentially of the Ward-Leonard type, and the voltage of each generator is controlled by a 2-stage magnestat which provides the generator excitation current. The output stage of the magnestat has a continuous rating of 3 kW. and a peak rating of 8 kW. 'IR drop' compensation is introduced to maintain a level speed characteristic. Stabilisation is effected by transient negative feed-back from both generator field and armature voltages. Tension control at the reel stand is obtained by constant armature current control of the reel motor. Compensation for reel build-up is provided by magnestat control of the motor field current.

Miscellaneous

During the year a 62,000 cu. ft./min. turbo-blower was delivered to the Workington Iron & Steel Co., and orders were received for two turbine-driven gas exhausters, each of 686,000 cu. ft./hr. capacity, for Woodall-Duckham, for South Africa and a 1,078,000 cu. ft./hr. turbine-driven gas booster for the Consett Iron Co., Ltd.

A new Ransomes & Rapier dragline commissi oneddur-ing the year and fitted with B.T.H. electrical equipment was supplied to the order of The United Steel Cos., Ltd., for service at Scunthorpe. It has a total weight of 800 tons, with a bucket capacity of 10 cu. yd., and is designed to strip the overburden, up to 60–70 ft. in depth, from the ore body.

Recent contracts include one from Sir William Arrol & Co., Ltd., for electrical machines and switchgear for three 10 ton ore unloaders for use in connection with Colville's new blast furnace plant at Ravenscraig.

The English Electric Co., Ltd.

Rolling Mills

During the year, a number of contracts for electrical equipment for rolling mills were completed and several new orders received for this class of plant. In the modernisation of a 4-stand tandem mill for cold rolling steel strip, new English Electric equipment was installed alongside existing plant. The additions included a 9,300 h.p. motor-generator set and motors (for some of the stands and the reel) totalling 9,800 h.p. Also started up during the year were the complete electrical drives and control equipment—totalling some 19,000 h.p.—for a new 5-stand cold tinplate mill in South Wales. The electrical equipment for a 2-stand tandem mill is now being installed at the same plant. English Electric magnetic amplifier fast response control systems are used on both of these tandem mills.

Typical hot mill drives installed during the year were for plants in the United Kingdom, Norway and France. Two in the U.K. are rated respectively at 2,650 h.p. and 3,650 h.p.—both for new steel plate mills—whilst a third, rated at 7,000 h.p., is replacing a steam engine for driving a slabbing mill. For a new continuous merchant bar, rod and skelp steel mill in Norway, English Electric supplied some 7,850 h.p. of rectifier-fed main drive motors and control equipment, together with most of the auxiliary drives throughout the plant.

The French contract covered an 8,050 h.p., 492 metre-ton "twin-drive" for a 160 in. 4-high reversing plate mill, and was the first of this type to be installed in that country. It is interesting to note that English Electric pioneered the idea of "twin drives" in 1922, and installed the first equipment in Great Britain, on a brass mill, in 1932. Such drives have now been supplied to customers in the U.K., Canada, and France, whilst another is being built for Spain.

The year saw the opening of a new non-ferrous plant in Canada, and for its four rolling mills English Electric supplied the main drives and control equipment, including two 150 h.p., one 300 h.p., and one 500 h.p. motors, together with many auxiliary motors, and switchgear and transformers for power distribution.

At present under construction are the main drives and control equipment for two structural mills of 2,750 h.p. and 2,500 h.p., respectively; a 5,000 h.p. blooming and slabbing mill; and an 8,000 h.p. "twin-drive" for a 50 in. blooming mill.

Among orders received is one for a 12,000 h.p. "twin-

Courtesy of The English Electric Co., Ltd.

LWC 200 portable welding equipment.

drive" for a high-lift slabbing mill, which will be one of the largest in the world. Other orders include drives for various processing lines, among them a continuous galvanising line of new design—believed to be the first of its type in Europe. Other drives on order include cold mill equipments for the U.K. and Australia; the electrification of a complete hot steel strip mill; rectifiers for the main drives of a continuous billet mill; and a 7,000 h.p. reversing roughing mill.

Rectifiers

English Electric rectifiers were again in demand during the year for use in many fields, including radio, traction and steel manufacture. For the new hot strip mill of Steel, Peech & Tozer, two 3,500 kW., one 1,000 kW. and two 500 kW. equipments were ordered, whilst a billet mill at the Irlam Works of the Lancashire Steel Corporation is fed by two 2,500 kW. installations. The various rectifiers are provided with grid control for motor starting, inching, and speed variation. Among overseas orders for auxiliary equipment for steelworks were two 1,500 kW. units for the Burnpur Works of the Indian Iron & Steel Co.

Welding Equipment

To meet the considerably increased demand for welding electrodes, production facilities have been extended, and the new electrode development laboratories inaugurated at the Accrington Works during the year will provide excellent testing and service facilities on all matters relating to welding electrodes and arc welding technique.

The range of portable welding equipments introduced last year have been well received. The LWC. 200 unit has proved exceedingly popular with sheet metal workers, agricu.tural engineers, blacksmiths, and others engaged on light fabrication. Many large new multi-operator plants have been supplied to shipyards at home and abroad, and to the heavy engineering industry. Their robust construction and reliability in service makes them a popular choice among welding engineers.

Miscellaneous

An order was received from the South Durham Steel & Iron Co., Ltd., for four 6,500 kW., 3,000 r.p.m. steam turbine driven generating sets for their Cargo Fleet Iron Works, Middlesbrough. Two of these are back pressure machines operating at 600 lb./sq. in. gauge, 790° F., with 190 lb./sq. in. gauge back pressure, and two are condensing sets operating at 185 lb./sq. in. gauge, 560° F., and exhausting at 28 in. vacuum.

An interesting transformer order covered a 15 MVA., 33 kV. arc furnace transformer designed with on-load tap changing equipment. It is the second unit of its type to be built in the United Kingdom, the first having been in successful operation at a Sheffield steel works for over a year.

The year 1955 has been characterised by the production in increasing quantities of the Company's Superform fuse switchboards and other standard lines. High rupturing capacity fuses and fusegear were supplied to power stations, cement and chemical industries, steel works and many other industrial plants, both at home and abroad.

(To be concluded)

Mechanical Handling

continued from page 97

Applications of electro-hydraulic equipment continue to multiply. The equipment itself is being improved; better seals play no small part in the increased mechanical advantage that has been achieved recently in lifting and other appliances, and the development of duplex systems of valves has allowed complex synchronised movements to be obtained. The use of electrical and electronic devices to activate the hydraulic cycle has led to a prolific development of automatic and semi-automatic movements in old and new types of handling equipment. Hydraulic cylinders are being increasingly used to cushion loads and take the shock of overloads and hydraulic thrustors to transmit smooth straight-line pressure. New uses have been found for pneumatic appliances, and electro-pneumatic devices have been applied to the tricky problem of level-control in hoppers and bins. Their usefulness will be extended by the recent development of valves capable of operating under very low pressures.

Included among the wealth of devices applicable to operational control are process controllers with provision for the remote handling of dangerous and toxic substances; variable speed controllers for conveyors or machine-tool feeds; proximity-switches for level control of bulk materials; and check weighers and batchers for continuous weighing and packing operations.

It is probably true to say that there are few handling problems for which a mechanical solution cannot be found, even though in some instances it may be so complicated as to make it uneconomical to apply. In all cases, however, full benefit is only to be obtained by making the fullest use of the equipment, and the trade unions can help considerably in this respect by eliminating restrictive practices.

British Oxygen Technical Service Department Move

New Premises at Cricklewood Opened

Sir Frederick Handley Page, C.B.E., speaking at the opening ceremony.

WHEN the Sales Technical Service Department of the British Oxygen Co., Ltd., was established in 1935 to give technical service to every industry using welding processes, the staff numbered fourteen. As techniques advanced and the number of new processes increased, the growing demands made on its services necessitated an enlargement of the Department, culminating in the erection of a new building at Cricklewood to house the staff—now numbering over sixty—and the equipment and facilities necessary to maintain a high standard of service to industry. The new premises were opened on February 20th, 1956, by Sir Frederick Handley Page, C.B.E.

The activities of the department are grouped under two sections: General Service and Process Development. The former covers all standard processes and equipment, and has a staff of experts to give practical advice and demonstrations to customers. Apart from Cricklewood, eight service branches are maintained in various parts of the country, to deal with routine problems of customers in their area. In cases where more complicated problems arise, these branches can call on the specialised advice of Cricklewood—as can also the overseas companies. The Process Development Section, as its name implies, deals with the development and application of welding and cutting processes, the work covering four process groups: Argonare; Argonaut; heavy cutting and allied flame processes; and flame hardening.

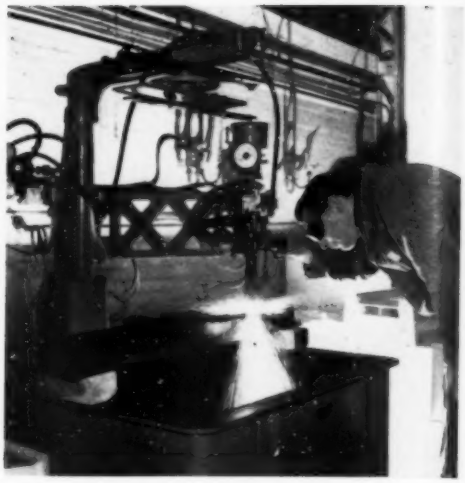
Of the two blocks comprising the new premises at Cricklewood, that fronting the roadway provides, in the main, office accommodation, but at one end is a lecture theatre, which can also be used for the showing of films. Behind the lecture theatre is a photographic department, with an exhibition of welding and cutting photographs between the two. The rear block houses the welding school, demonstration shop, cutting shop, process development shop, machine shop, and liquid oxygen house.

One of the most important ways in which the Company serves industry is through the welding school. The school at Cricklewood can accommodate 45 gas process and 9 Argonare welding students. The course varies in length, that for British Oxygen staff being 9 months: the basic welding course lasts from 4 to 8 weeks, and a more comprehensive course takes 3 months. In a year, some 500 students receive training in this school, in addition to those trained at the six schools attached to service branches.

As its name suggests, the demonstration shop is used for demonstrations to customers of gas and shielded-arc welding, and of various cutting processes. The processes

General view of the new premises.

General view of the welding school.



Powder cutting stainless steel.

demonstrated in the shielded-arc field include : manual Argonare welding, where a tungsten electrode is used and the arc is shielded with argon ; Argonare machine welding ; Argonare spot welding ; and Argonaut welding. The last-named is a manual process in which a consumable electrode is used in place of the tungsten electrode of the Argonare process, and in which automatic regulation is provided. Argonare spot welding enables spot welds to be made when access is available to one side of the work only.

The range of machines available for demonstrating cutting processes include a 36 in. Universal cutting machine capable of cutting steel 6 in. thick within the 36 in. radius of the cutting arm ; a heavier version with a 55 in. arm and capable of cutting 12 in. thick steel ; a Bison cutting machine, working on the cross carriage principle, which can be operated by magnetic tracing, from wood templates or from drawings, and which is fitted with Thyratron speed control ; a Beagle transportable cutting machine which enables bevels of constant angle to be reproduced on curves of changing radii ; a portable straight line cutting machine ; and a Bantam cutting machine—the newest of the lightweight portable cutting machines for steel up to 2 in. in thickness.

Further demonstrations of cutting processes are featured in the cutting shop, which also carries out development work for the process section, but these are mainly concerned with specialised applications. One of the most notable advances in the cutting field has been the introduction of the powder process for cutting stainless steel, cast iron, and some of the non-ferrous metals. The introduction of iron powder into the cutting stream enables accurate cuts to be made in these materials. Stainless steel up to 42 in. thick can be cut by this process. Allied to this is the powder lancing technique, whereby long sand cores can be removed from steel castings ; this process makes use of the high temperature reaction between iron powder and oxygen and the sand core is reduced to molten slag. This technique can also be used for breaking up concrete masses, such as the foundations of blast furnaces.

Fitted with a suitable nozzle, the cutting blowpipe can be used for gouging, which is a method of cutting grooves in steel, and may be used for the removal of defects in the surface of the metal, and for plate preparation. Another use of oxygen in the steel industry is the deseaming process, which has replaced chipping for cleaning up the surface of steel billets.

A major development in cutting has been the production of equipment for cutting very thick blocks, whether in the decapitation of ingots or in the reduction of such material to a size suitable for charging into the melting furnace. It is now possible to cut steel up to 50 in. in thickness, but the steel industry requires bigger cuts for forging ingots, and experiments are now in progress to raise the figure to 108 in. Also concerned with ingots is the recently developed oxy-propane burner, which is on trial in three steelworks, where it is used to keep the top of the ingots molten in order to assist feeding, and so to increase the yield.

Reference has already been made to some of the work in progress in the Process Development Section, particularly in the cutting field. In Argonare welding, techniques for welding the newer metals, such as titanium, zirconium, etc., are being investigated. In the case of the former metal, difficulty is presented by atmospheric contamination. Work is also in progress on automatic Argonaut welding of tubes in heat treatable low alloy steel. The advantages of the process are the amount of metal deposited in one pass ; the speed of welding ; and the high quality of the weld structure. The Section is also developing automatic arc length control, which will give a better quality weld.

75th Annual Meeting of S.C.I.

On the occasion of the 75th Annual Meeting of the Society of Chemical Industry, which is being held in London from 9th to 14th July, a series of lectures will be given under the title of "Achievements of Industrial Chemistry." The series will be introduced by Dr. L. A. Jordan, C.B.E., on 11th July, speaking on "Modern Methods of Research." Thereafter, lectures will fall into two parallel series with the general titles of "Products of Industrial Chemistry" and "Tools of Industrial Chemistry." The second series includes a lecture on Thursday, 12th July, on "Metals as Plant Construction Materials," by Dr. N. P. Inglis.

Hot Work Die Steels

Properties Suggest Other High Temperature Uses

HOT work die steels have, for many years, been used successfully for tools requiring high toughness and strength at high temperatures. A number of these steels have a wide hardening range, and their potentialities in relation to high temperature problems in high-speed aircraft should be explored. Compositions of four such steels are given in Table I. These steels have low thermal coefficients of expansion, which are quite similar to those for titanium and ferritic stainless steels. The chromium types A and B are tougher than ordinary chromium steels, while steels C and D have a resistance to softening equivalent to that of 9–12% tungsten hot work steel. The latter, a newly developed material, also has a lower hardening temperature than the high tungsten steels. Since C and D undergo secondary hardening on tempering, they are highly resistant to softening when subjected to elevated temperature service in the quenched and tempered condition.

The excellent strength and ductility of steels A and B at temperatures as high as 1,000° F. (538° C.) are shown in Table II, which also gives the properties of the nickel-chromium steel S.A.E. 4340. Mechanical properties at elevated temperatures depend somewhat on room-temperature properties, and maximum room-temperature properties attainable may depend considerably on the size of the part heat treated, particularly in the case of S.A.E. 4340. Hence, it is important to note that the properties of steels A and B were obtained for 4-in. sections, air-cooled and tempered, whereas the properties for S.A.E. 4340 were obtained on ¼-in. rounds, oil-quenched and tempered.

Table III gives elevated temperature tensile properties of steel D subjected to various hardening and tempering treatments. Highest tensile and yield strengths are generally obtained with the 2,100° F. (1,149° C.) austenitising treatment, even with a 6-hour temper at 1,225° F. (663° C.), but higher elongation and reduction of area are obtained with the lower austenitising temperature of 1,950° F. (1,066° C.). In comparison with steel A, the added tungsten and molybdenum in steel D increase the short-time heat resistance, especially beyond 1,100° F. (593° C.). The higher carbon content of steel D, com-

TABLE I.—COMPOSITION OF FOUR HOT WORK DIE STEELS

Steel	C %	Mn %	Si %	Ni %	Cr %	V %	W %	Mo %
A	0·38	0·34	1·10	0·15	5·21	0·40	—	1·38
B	0·32	0·44	0·95	0·12	5·00	0·18	1·31	1·36
C	0·43	0·38	0·32	0·10	2·20	0·63	1·00	0·71
D	0·53	0·32	0·21	0·11	1·37	1·33	2·79	1·55

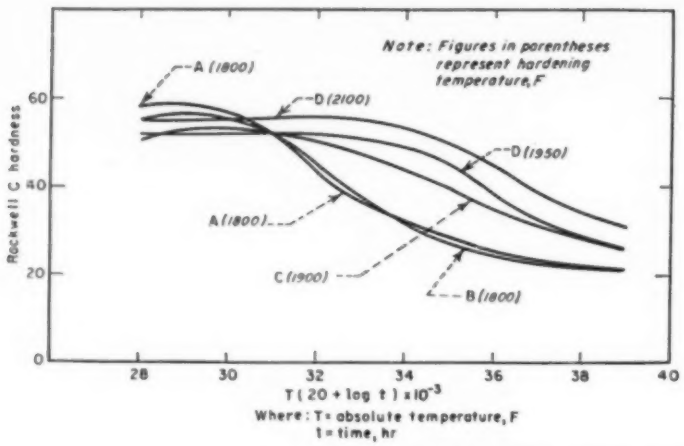
* Digested from article by Edward A. Loria in *Materials and Methods*, August, 1955, pp. 94-97.

TABLE II.—ELEVATED TEMPERATURE TENSILE PROPERTIES OF STEELS A AND B

Steel	Heat Treatment	Test Temperature (° F.)	Test Temperature (° C.)	Ultimate Tensile Stress (lb./sq. in.)	Ultimate Tensile Stress (tons/sq. in.)	Yield Stress (0·2% Offset) (lb./sq. in.)	Yield Stress (0·2% Offset) (tons/sq. in.)	Elongation (%)	Reduction of Area (%)
A	Air cooled from 1,800° F. (982° C.) and tempered 3 hours at 1,100° F. (593° C.) to Rc 44	80	27	217,000	96·8	184,000	82·2	13	40
		800	427	171,000	76·2	137,000	61·2	17	56
		900	482	155,000	69·1	125,000	55·8	20	65
		1,000	538	145,000	64·6	105,000	46·8	19	65
		1,100	593	110,000	49·1	88,000	39·3	21	69
B	Air cooled from 1,800° F. (982° C.) and tempered 3 hours at 1,100° F. (593° C.) to Rc 44	80	27	205,000	91·5	185 000	82·6	12	42
		800	427	182,000	81·2	152,000	67·8	18	49
		900	482	167,000	74·5	147,000	65·6	19	55
		1,000	538	137,000	61·2	120,000	53·6	25	64
		1,100	593	121,000	53·9	103,000	45·9	18	72
S.A.E. 4340	Oil quenched from 1,550° F. (843° C.) and tempered 2 hours at 850° F. (454° C.) to Rc 43	80	27	198,000	88·3	188,000	84·0	14	53
		600	316	177,000	79·0	146,000	65·2	21	65
		700	371	164,000	73·2	138,000	61·6	20	71
		800	427	142,000	63·3	126,000	56·2	22	68
	Oil quenched from 1,550° F. (843° C.) and tempered 2 hours at 1,170° F. (632° C.) to Rc 32	80	27	143,000	63·8	129,000	57·6	20	62
		500	260	140,000	62·5	107,000	47·8	21	53
		700	371	122,000	54·4	96,000	42·8	25	72
		850	454	103,000	45·9	86,000	38·4	26	76
		1,000	538	80,000	35·7	58,000	25·9	34	87

TABLE III.—ELEVATED TEMPERATURE TENSILE PROPERTIES OF STEEL D

Heat Treatment	Test Temperature (° F.)	Test Temperature (° C.)	Ultimate Tensile Stress (lb./sq. in.)	Ultimate Tensile Stress (tons/sq. in.)	Yield Stress (0·2% offset) (lb./sq. in.)	Yield Stress (0·2% offset) (tons/sq. in.)	Elongation (%)	Reduction of Area (%)
Oil quenched from 1,950° F. (1,066° C.) and tempered 3 hours at 1,250° F. (677° C.) to Rc 46	80	27	214,000	95·5	204,000	91·1	10	30
	800	427	173,000	77·2	153,000	68·2	11	40
	1,000	538	142,000	63·3	126,000	56·2	14	48
	1,200	649	93,000	41·5	72,000	32·1	13	28
Oil quenched from 1,950° F. (1,066° C.) and tempered 2 hours at 1,150° F. (621° C.) to Rc 52	80	27	256,000	114·2	232,000	103·5	8	25
	1,000	538	187,000	83·5	162,000	72·3	13	39
Oil quenched from 2,100° F. (1,149° C.) and tempered 6 hours at 1,225° F. (663° C.) to Rc 49	80	27	245,000	109·2	227,000	101·3	7	21
	800	427	198,000	88·4	178,000	79·5	10	34
	900	482	193,000	86·1	174,000	77·6	8	20
	1,000	538	176,000	78·5	158,000	70·5	7	19
Oil quenched from 2,100° F. (1,149° C.) and tempered 4 hours at 1,225° F. (663° C.) to Rc 51	80	27	259,000	115·7	243,000	108·5	6	19
	800	427	209,000	93·3	188,000	84·0	7	27
Annealed at 1,600° F. (871° C.) and tempered 16 hours at 1,400° F. (760° C.) to Rc 10	80	27	88,000	39·3	60,000	26·8	29	56



HOW TO USE MASTER TEMPERING CURVE

Given: Steel A, tempered to Rc 45

To Find: Hardness of steel A after being subjected to service temperature of 1,000° F. for 200 hr.

First determine what length of time at the proposed service temperature would have been required to obtain the present or starting temper. From the chart, parameter for steel A at Rc 45 is about 31,900. Thus,

$$31{,}900 = T\,(20 + \log t) = 1{,}460\,(20 + \log t)$$
$$\log t = 31{,}900/1{,}460 - 20 \cong 1.85$$
$$t \cong 70 \text{ hr.}$$

In other words, steel A at Rc 45 has had a tempering treatment *equivalent* to about 70 hr. at 1,000° F. To find its hardness after 200 hr. service at 1,000° F. (or a total equivalent exposure of 270 hr. at 1,000° F.):

$$T\,(20 + \log t) = 1{,}460\,(20 + \log 270 \cong 1{,}460 \times 22.432 \cong 32{,}700$$

From the chart, parameter of 32,700 for steel A represents a hardness of about Rc 40.

Fig 1.—Master tempering curves for the four steels

pared with the other steels, makes it possible to attain much higher strengths.

The elevated temperature tensile data given are based on short-time exposures. Within a certain temperature range these properties are maintained during long exposures, but at higher temperatures they decrease as a function of time. Both effects are "structure-sensitive phenomena," characteristics of each individual steel. One way to estimate the temperature ranges in which the desired properties will remain relatively constant for a certain time is by means of master tempering curves. Such curves show the combined effect of temperature and exposure time on hardness.

Master tempering curves for the four die steels are reproduced in Fig. 1. Note the flatness of the curve for steel D, which shows only a three-point drop in hardness over the extremely wide parameter range of 28,000 to 35,000. In the 1,150–1,350° F. (621–732° C.) range, steel D is more temper-resistant than commercial 18-4-1 high speed steel. Specifically, two-hour cumulative tempering treatments at 1,200–1,350° F. (649–732° C.) drop the hardness from 56 to 42 Rc for steel D, compared with 52 to 38 Rc for 18-4-1. Steel D is much superior to steel A in resistance to tempering, and steel C has intermediate temper resistance.

Comparing these die steels with S.A.E. 4340 steel, it is stated that latter, heat treated to Rc 43, loses hardness rapidly when subjected to temperatures over 850° F. (454° C.). A 2-hour exposure at 1,000° F. (538° C.) may drop its hardness to Rc 35 or lower. Steels A and B heat treated to Rc 44, however, can be exposed to 1,000° F. (538° C.) for as long as 10 hours without losing any hardness, and will have a hardness of Rc 40 or higher even after a 100-hour exposure.

It has been thought for some time that exposures at temperatures under the tempering temperature would not produce any significant change in mechanical properties. This theory seems to be supported by a recent National Bureau of Standards study of steel S.A.E. 4340, heat treated to 260,000–280,000 lb./sq. in. (116–125 tons/sq. in.), in which practically no changes were observed after 200 hours exposure at 400° F. (204° C.). Also, a study by Meickle and Binning on several low alloy structural steels at temperatures up to 660° F. (349° C.) indicated no additional loss of mechanical properties on heating for periods up to 1,000 hr.

TABLE IV.—ROOM TEMPERATURE TENSILE PROPERTIES OF STEEL A SHEET*

Heat Treatment	Heat†	Ultimate Tensile Stress				Yield Stress (0·2% Offset)				Elongation (%)	
		Average		Range		Average		Range		Average	Range
		lb./sq. in.	tons/sq. in.	lb./sq. in.	tons/sq. in.	lb./sq. in.	tons/sq. in.	lb./sq. in.	tons/sq. in.		
Annealed at 1,450° F. (777° C.) and cooled at 10° F. (5·6° C.) per hour to Rb 95	H	108,000	48·2	106,000–109,000	47·3–48·6	83,000	37·1	80,000–86,000	35·7–38·4	17	16–19
Annealed at 1,550° F. (843° C.) and cooled at 10° F. (5·6° C.) per hour to Rb 85	T	89,000	39·9	85,000–91,000	37·9–40·6	46,000	20·5	45,000–48,000	20·1–21·4	20	16–23
Annealed as above, then salt quenched from 1,800° F. (982° C.), air cooled from 1,000° F. (538° C.), and double tempered 4 hours at 1,125° F. (607° C.) to Rc 42–44	H	192,000	85·7	191,000–193,000	85·2–86·2	166,000	74·1	164,000–167,000	73·2–74·5	7·5	7·0–8·0
	T	193,000	86·2	192,000–195,000	85·7–87·1	169,000	75·4	167,000–170,000	74·5–75·8	7·0	7·0–7·5
Annealed as above, then salt quenched from 1,805° F. (982° C.), air cooled from 1,000° F. (538° C.), and double tempered 4 hours at 1,100° F. (593° C.) to Rc 42–46	H	204,000	91·1	203,000–205,000	90·7–91·5	176,000	78·5	175,000–178,000	78·2–79·4	7·0	6·0–8·0
	T	209,000	93·3	207,000–212,000	92·4–94·6	179,000	79·9	177,000–181,000	79·0–80·8	6·5	6·0–7·0

* Hot rolled, annealed and pickled, 0·040 × 36 × 72 in. All values based on five sheets.

† Composition:

	C %	Mn %	Si %	Cr %	Mo %	V %
Heat H	0·38	0·41	1·05	5·01	1·33	0·33
Heat T	0·34	0·34	1·00	5·02	1·37	0·32

Room-temperature tensile properties of 0·040-in. sheet from two heats of steel A are given in Table IV. The narrow ranges throughout indicate a high degree of uniformity among the different sheets tested, and the results obtained for two different hardening and tempering treatments indicate good reproducibility between heats despite normal variations in composition. Mill-annealed properties indicate that forming of these sheets would not be a problem. Note that hardness as low as Rb 95 can be obtained with a 1,420–1,440° F. (777–782° C.) sub-critical anneal. The softer sheet can be bent 80° without microscopic cracking. Spring back from a 90° bend is 12° for the Rb 95 sheet and 8° for the Rb 85 sheet; this difference would be important in setting up forming dies for uniform production. Similarly, the as-annealed properties of steel D (Table III) indicate that wire drawing would not be a problem. The excellent yield and ultimate strengths of steel D at elevated temperatures would make it a good choice for coiled helical springs which must be highly stressed, and which must operate at elevated temperatures with little or no set.

Zinc Development Association's New Offices

Move from Oxford to London

THE Zinc Development Association, which for some years has been located in Oxford, is now established in its new headquarters at 34, Berkeley Square, London, W.1. In opening the premises, the President of the Board of Trade, Mr. Peter Thorneycroft, M.P., welcomed the Association to London, and spoke of the way in which it so freely helped users of zinc, not only in the United Kingdom, but throughout the world. He referred to the Association as a most co-operative body and one with whom the Board of Trade had always maintained the most friendly relations. The President took the opportunity to pay tribute to Mr. W. Mure, the past Chairman of the Association, for his services as joint Controller of Non-Ferrous Metals during the war, and also thanked Mr. R. Lewis Stubbs, the Director, for his work at the International Materials Conference.

Mr. D. P. C. Neave, Chairman of the Zinc Development Association and Vice-Chairman of the Consolidated Zinc Corporation, in thanking the President, drew attention to the unique position occupied by development associations in Britain. They had a reputation for providing impartial and accurate information to enquirers. The Z.D.A. and its affiliated associations—the Hot Dip Galvanizers, the Zinc Alloy Die Casters and the Zinc Pigment Development Associations—had in recent years greatly extended their work and were well-known to zinc users everywhere. The exchange of information which had taken place at the various Conferences organised by the Associations had stimulated interest in zinc so that it was now being used to better advantage than ever, and it was interesting to note that the consumption of zinc had reached a new high level in 1955. Most of the zinc used in Britain was of Commonwealth origin, and Canada and Australia had contributed very generously to the Zinc Development Association, and had made possible its move to London, where it would be in daily contact with the principal users. The credit for making the policy decision in connection with the new offices belonged entirely to his immediate predecessor, Mr. William Mure, and everyone felt that this occasion made a suitable culmination to his three years as a most successful Chairman of the Association.

View of the entrance hall. The information room on the right houses a permanent display of exhibits and charts showing the main properties of zinc.

The New Premises

No. 34, Berkeley Square, a house built in mid-Victorian times, has been modernized by the installation of a lift, but care has been taken not to destroy its essential character. At the same time, the best modern ideas in interior decoration and equipment have been incorporated. All the decorations and furniture have been designed by James Cubitt & Partners, architects, and the new building will form a centre where consumers of zinc in Britain and all over the world can obtain information on zinc and its uses.

The ground floor contains the library and a small waiting room in which there are exhibits and charts showing the main properties of zinc. A staircase from the waiting room leads to the basement and to an exhibition room which will be used for special exhibitions which will be changed from time to time. On the first floor is the council room, which has been fitted up for showing films, and the director's office. These two rooms are connected by folding doors which can be opened for receptions. On the second floor are the offices of the chief technical officer, the secretary and the technical officers concerned with galvanizing. On the third floor are the offices of the technical officers dealing with die casting, the production engineers and the main typing pool.

NEWS AND ANNOUNCEMENTS

Institute of Metals Spring Meeting

THE Spring Meeting of the Institute of Metals will be held in London from Tuesday to Friday, 10th–13th April, 1956. The meeting will open at 7 p.m. on Tuesday, 10th April, at the Royal Institution, Albemarle Street, London, W.1, with the presentation of the Institute's May Lecture by Dr. Willis Jackson, F.R.S., whose subject will be "Ferro-electrics—The Dielectric Analogue of Ferro-magnetics." The remainder of the meeting, unless otherwise stated, will be held at Church House, Great Smith Street, London, S.W.1.

The Annual General Meeting of the Institute will be held in the morning of Wednesday, April 11th, following which Major C. J. P. Ball, D.S.O., M.C., will deliver his Presidential Address on "The History of Magnesium." The Metallurgical Engineering Committee has arranged an all-day symposium on "The Final Forming and Shaping of Wrought Non-Ferrous Metals," and the recently formed Nuclear Energy Committee has arranged a discussion on materials for nuclear power engineering. There will also be discussions on the themes: "Powder Metallurgy"; "Embrittlement and Fracture"; "Rolling Textures and Recrystallisation"; and "Alloy Thermodynamics." Details of the papers to be presented at the technical sessions are set out below:—

Wednesday, April 11th.

2.30 p.m.–4.30 p.m. Theme: Materials for Nuclear Power Engineering.

Metallurgical Research and Development for Nuclear Power, by H. K. HARDY.

Metallurgical Research Problems Associated with Nuclear Energy, by J. G. BALL.

Selection of Canning Materials for Reactors Cooled by Sodium/Potassium, and Carbon Dioxide, by A. B. MCINTOSH and K. Q. BAGLEY.

Thursday, April 12th.

Programme A

10 a.m.–12.45 p.m. and 2.30 p.m.–5 p.m. Symposium on "The Final Forming and Shaping of Wrought Non-Ferrous Metals." The papers will be presented by a rapporteur (PROFESSOR F. C. THOMPSON).

Research in Some Metal-Forming and Shaping Operations, by W. JOHNSON.

The Deep Drawing and Spinning of Sheet Metal, with Particular Reference to Non-Ferrous Materials, by J. A. GRAINGER.

Rubber Pressing, by J. FIELDING.

Stretch-Forming of Non-Ferrous Metals, by R. D. EDWARDS.

Cold Roll-Forming and Manipulation of Light Gauge Sections, by E. GRIFFIN.

Bending and Allied Forming Operations, by T. G. PERRY.

The Machining Properties of Non-Ferrous Metals, by D. F. GALLOWAY.

The Hot Forming of Magnesium Alloys, by R. G. WILKINSON.

Programme B

10 a.m.–12.45 p.m. (*a*) Theme: Powder Metallurgy. A discussion based on the following papers which will be presented by a rapporteur (DR. J. C. CHASTON).

Porosity and Permeability Changes During the Sintering of Copper Powder, by G. ARTHUR.

The Sintering, Fabrication and Properties of Thorium, by M. D. SMITH and R. W. K. HONEYCOMBE.

The Manufacture and Properties of High-Strength Nickel-Tungsten Alloys, by M. DAVIS, C. E. DENSEM and J. H. RENDALL.

(*b*) Theme: Embrittlement and Fracture. A discussion based on the following papers which will be presented by a rapporteur (DR. W. A. BAKER).

Intercrystalline Fracture of Beta-Brasses Containing Aluminium, by E. C. W. PERRYMAN.

The Effect of Zirconium and Titanium on the Intercrystalline-Cracking Tendency of Beta-Brasses, by E. C. W. PERRYMAN and R. J. GOODWIN.

The Mechanism of Embrittlement by a Liquid Phase, by R. EBORALL and P. GREGORY.

2.30 p.m.–5 p.m. Theme: Rolling Textures and Recrystallisation. A discussion based on the following papers which will be presented by a rapporteur (DR. T. LL. RICHARDS).

Surface Nucleation in the Recrystallisation of Aluminium Single Crystals, by C. D. GRAHAM and R. MADDIN.

Deformation and Annealing Textures in Thorium, by R. E. SMALLMAN.

Textures in Face-Centred Cubic Metals and Alloys, by R. E. SMALLMAN.

On the Recrystallisation of Cold-Rolled Commercially Pure Titanium, by I. OBINATA and K. NISHMURA.

Friday, April 13th.

10 a.m.–12.45 p.m. Theme: Alloy Thermodynamics. A discussion, arranged by the Metal Physics Committee, to be opened by DR. J. FRIEDEL (Paris).

Institute of Metal Finishing Conference

THE Annual Conference of the Institute of Metal Finishing has come to be regarded as a technical and social landmark in the metal-finishing industry, and the programme for this year's Conference, which is to be held at the Norbreck Hydro, Blackpool, from April 17th–21st, shows that plans have been drawn up to make the function as attractive as ever.

A total of fifteen papers will be presented for discussion at five technical sessions spread over three days. Details of the papers are as follows:—

Wednesday, April 18th.

9.30 a.m.–12.30 p.m.

Alkaline Electrobrightening and Anodising of Aluminium, by N. D. PULLEN and B. A. SCOTT.

Some Studies of Phosphoric Acid-Based Chemical Brightening Solutions for Aluminium, by A. W. BRACE and T. S. DE GROMOBOY.

Studies in Bright Anodising by the Ammonium Bifluoride-Nitric Acid Process, by G. E. GARDAM and R. PEEK.

Bright Anodised Aluminium and its Employment in Automoible Manufacture, by F. BAUMANN and H. NEUNZIG.

2.30 p.m.–4.30 p.m.

Smoothing of Mild Steel by Barrel Treatment in Oxalic Acid-Hydrogen Peroxide Solution, by K. SACHS and MISS M. ODGERS.

Tin-Zinc Alloy Deposition from Stannate-Complexone Solutions, by R. M. ANGLES and A. E. DAVIES.

A Preliminary Investigation of the Formation of Cracks in Hard Chromium Electrodeposits and the Evolution of Hydrogen during Deposition, by C. P. BRITTAIN and G. C. SMITH.

Thursday, April 19th.

9.30 a.m.–12.30 p.m.

The Engineering Aspect of Electroplating Plant, by H. C. CLEMENTS.

Automatic Plant for Bright Zinc Plating, by J. CHADWICK.

Friday, April 20th.

9.30 a.m.–12.30 p.m.

Laboratory Evaluation of Paint Durability—Accelerated Weathering Tests, by T. R. BULLETT.

Polytetrafluorethylene Dispersions for Metal Finishing, by E. M. ELLIOTT.

The Painting of Magnesium Alloy Surfaces and the Principle of Surface Sealing, by W. F. HIGGINS.

2.30 p.m.–4.30 p.m.

Industrial Nickel Coating by Chemical Catalytic Reduction, by G. GUTZEIT.

Practical Brush-Plating, by D. H. HUGHES.

Electroformed Spray Masks, by P. SPIRO.

Apart from this strong technical programme, a number of social events have been planned for the evenings during the Conference, culminating in a banquet and ball on the Friday evening.

Institute of Welding Spring Meeting

THE Annual Spring Meeting of the Institute of Welding is being held this year in the Eastern Counties' Area, and it will comprise, as usual, a number of works visits and technical sessions. The latter are being arranged for the mornings of Friday, 4th May, and Saturday, 5th May, and will be held in the Ballroom of the Cavendish Hotel, Felixstowe. The following papers will be presented and discussed :—

4th May.

The Case for Site Welding, by J. H. SMITH.

Welding and the Structural Steelwork Industry—a Report of the Structural Sub-Committee of the Institute of Welding.

5th May.

Welding Progress in a General Engineering Workshop, by J. A. EDWARDS and J. O. H. NICE.

Recent Progress in the Fabrication of Thermoplastic Materials, by G. HAIM.

Visitors will be welcome at the technical sessions.

Steel Heat Treatment Course

A VACATION Day Course on "The Heat Treatment of Steel" will be held in the Department of Metallurgy, Battersea Polytechnic, from Tuesday, 10th April, to Friday, 13th April, inclusive. Professor F. C. Thompson will deliver an address on "Decomposition of Austenite," by way of introduction to the course, which will include lectures on the following topics : "Critical Review of Current Heat Treatment Practice" (R. J. Brown) ; "Isothermal and Continuous Cooling Transformations" (G. Mayer) ; "Hardenability" (W. Steven) ; "Tempering Quenched Steel" and "Overheating and Burning of Steel and Temper Brittleness" (J. Nutting) ; "Controlled Atmospheres in Heat Treatment" (I. Jenkins) ; "Heat Treatment of Alloy Steels" (W. D. Biggs) ; and "Special Steels and Special Heat Treatments" (E. Johnson).

The fee for the Course is £4 4s. 0d., and accommodation is available at the Polytechnic Hostels at a charge of £5 5s. 0d. for residence and main meals from Monday evening to Saturday morning. Applications for the course and for hostel accommodation should be sent to the Secretary (H.T. Vac. Course), Battersea Polytechnic, London, S.W.11.

Physical Society Exhibition

SIR JOHN COCKCROFT, K.C.B., K.B.E., F.R.S., will open the Physical Society's 40th Annual Exhibition of Scientific Instruments and Apparatus in the Royal Horticultural Society's New Hall, Westminster, at 11 a.m. on Monday, 14th May, 1956. The exhibition, which will continue until Thursday, 17th May, is being held in both the Old and New Halls, and the extra space available will make for easier access for visitors.

The policy of the Society, to show as much as possible of that which is novel and new, has not been changed, and it is anticipated that the standard of the exhibition in 1956 will be higher than ever before. In addition, a greater number of universities, colleges and research organisations have agreed to take part, thus increasing the proportion of purely research exhibits. As is usual, exhibits will show the trend of instrumentation in industry, research, and teaching for the next twelve months. Prominently displayed will be much equipment concerned with the peaceful use of atomic energy. Other exhibits include theoretical and practical work showing developments and application of computers ; in particular their application to automatic control in industry.

The hours of opening are : Monday, 2 p.m. to 8 p.m. ; Tuesday and Wednesday, 10 a.m. to 8 p.m. ; Thursday, 10 a.m. to 5 p.m. Admission is by ticket, and these will be available at the end of March from the Physical Society, 1, Lowther Gardens, Prince Consort Road, London, S.W.7 : a stamped and addressed envelope should be enclosed with the application.

Symposium on Corrosion Prevention in Packaging and Storage

ORGANISED jointly by the Birmingham and Midlands Section and the Corrosion Group of the Society of Chemical Industry, a symposium on "Corrosion Prevention in Packaging and Storage" will be held on Wednesday and Thursday, 11th and 12th April, 1956, in the Chemistry Lecture Theatre of the University of Birmingham. On the Wednesday afternoon, the following papers will be discussed : "The Control of Atmospheric Corrosion of Metals in Storage and Transit" ; "Practical Methods of Preventing Corrosion in Packages" ; and "The Selection of the Packaging Material." On Thursday morning, discussion will centre on "Testing Packaging Materials" ; "Packaging Service Equipment" ; and "Some Industrial Problems in Packaging and Storage." The conference fee for non-members of the Society of Chemical Industry is £1 1s. 0d., and further particulars and registration forms can be obtained from the Assistant Secretary, Society of Chemical Industry, 56, Victoria Street, London, S.W.1.

Summer School of Welding

THE Sixth Summer School of Welding organised by the British Welding Research Association will be held at Ashorne Hill near Leamington Spa, Warwickshire, from Monday, 18th June to Saturday, 23rd June, 1956. This year an attempt is being made to provide a course designed to meet the increasing interest in specialised subjects. The course will therefore appeal particularly to managerial staff, research workers, engineers and all those who are in any way concerned with the selection of materials or processes for welding.

The course is divided into four groups—Gas Shielded Welding ; Resistance Welding ; Metallurgy and Physics of Welding ; and Inspection, Testing and Quality Control in Welding Processes—each student being allowed to register for one group only. In contrast to previous summer schools, demonstrations relevant to the particular courses will be arranged in collaboration with the electrode and welding equipment manufacturers, and more time will be devoted to this part of the programme than was the case in the past.

The school is open to all, and those wishing to attend, or send representatives from their organisations, should obtain application forms as soon as possible. Application forms and programmes of lectures are obtainable from : The Organising Secretary, 6th Summer School of Welding, British Welding Research Association, 29, Park Crescent, London, W.1.

Welding Design Course

A FURTHER Welding Design Course to assist draughtsmen and designers of welded structures and fabrications, will commence on Monday, 14th May, at the Head Office of Quasi-Arc, Ltd., in Bilston, Staffordshire. The course, which will deal with all aspects of arc welding, consists of lectures, demonstrations, films and visits to works, and is similar to the evening courses which have attracted over 250 students to various centres all over the country this season. This course lasts for one week and provides concentrated training for students who are not able to attend evening sessions. Further details, together with the enrolment form, can be obtained from the Constructional Design Department at Bilston.

Beilby Memorial Awards, 1955

THE Administrators of the Sir George Beilby Memorial Fund, representing the Institute of Metals, the Royal Institute of Chemistry and the Society of Chemical Industry, have made awards from the Fund for 1955, each of 150 guineas, to :—

F. D. RICHARDSON, B.Sc., Ph.D.(Lond.), in recognition of his work on the thermodynamic properties of high temperature systems, with special reference to iron smelting and steelmaking.

F. WORMWELL, M.Sc.(Manc.), Ph. D., D.Sc.(Lond.), in recognition of his work on surface reactions, with special reference to the mechanism of metallic corrosion, oxidation and passivation processes.

Awards from the Fund are made to British investigators in science as a mark of appreciation of distinguished work, particularly in such fields as fuel economy, chemical engineering and metallurgy, in which Sir George Beilby's special interests lay. In general, the awards are not applicable to more senior investigators but are granted as an encouragement to relatively young men who have done independent work of exceptional merit over a period of years. The Administrators are free, however, to interpret this general provision very widely in specific instances, as they have done this year.

Automatic Laboratory Film

BAIRD AND TATLOCK (LONDON) LTD., announce that the film on their Analmatic automatic laboratories is available for loan to interested societies and organisations. The film is taken from the B.B.C. television programme on automatic laboratories which appeared in " Science Review " last year.

Personal News

DR. A. H. SULLY, who has been Associate Director of the British Steel Castings Research Association since March, 1955, has been appointed Director of Research as from 1st March, 1956, in succession to PROFESSOR R. J. SARJANT, O.B.E., who will continue to act in an advisory capacity to the Association.

MR. H. R. WALTON, Sales Manager of Fisher Governor Co., Ltd., has been appointed a Director.

MR. T. LAND, Managing Director of Land Pyrometers, Ltd., of Sheffield, recently presented a paper on " Suction Pyrometry " to the Iron and Steel Instrumentation Conference in Pittsburgh.

MR. C. SHAW, a Director of Shaw Processes, Ltd., has been visiting South Africa, calling at Rome and Cairo to arrange agencies for the Shaw process of precision casting, and visiting the ethyl silicate plant he started in Johannesburg and the precision casting foundries in Johannesburg, Durban and Capetown.

MR. F. HAIGH has been appointed Commercial Manager of the Steel Foundry Department of Edgar Allen & Co., Ltd., in succession to MR. W. LONGDEN, who is undertaking work of a specialised nature in connection with the investigation of costs and selling prices.

MR. C. W. HOTCHEN has been appointed Works Manager (Production) at the factory of Smiths Aircraft Instruments, Ltd., Cheltenham.

MR. C. O. BOYSE has been appointed a Director of British Insulated Callender's Cables, Ltd.

Obituary

We regret to record the deaths of the following :

MR. R. ELSDON, formerly Librarian of the Joint Library of the Iron and Steel Institute and Institute of Metals, who died on February 21st, 1956. Born in London in 1887, Mr. Elsdon joined the staff of the Iron and Steel Institute in 1904 and became Librarian in 1908, a post he held until 1937, when the libraries of the two institutes were amalgamated. Under his charge, the collection of volumes in the Iron and Steel Institute Library increased from 2,000 to 30,000 and the number of books borrowed from 100 to 12,000 per annum. Among the innovations introduced by Mr. Elsdon were the loan of volumes to members and the compilation of bibliographies : he also began and developed the Information Department. In addition to his many duties as Librarian, Mr. Elsdon for many years served as an abstractor for the *Journal* and compiled the indexes. Throughout his long association with the Library, he devoted his energies to building it up to be of the greatest service to members, and to the maintenance of a close co-operation with other British and foreign technical libraries. Mr. Elsdon retired in December, 1951, and in 1952 he was elected an Honorary Member of the Iron and Steel Institute.

MR. J. MCNEIL, whose death occurred suddenly in Bombay, on February 21st, 1956. Born in 1899, Mr. McNeil, who was educated at the Royal Technical College, Glasgow, joined the Development and Research Department of The Mond Nickel Co., Ltd., in 1927. From 1940 until 1944, he acted as the Company's Technical Representative in Sydney, and was appointed Manager of their Technical Office in Bombay in 1944.

MR. J. W. WALKER, a Director of Sanderson Brothers & Newbould, Ltd., who died on February 28th. Mr. Walker joined the Company in 1936 and became Works Director in 1943—a position he held until 1954. A member of the Institution of Production Engineers, he was President of the Sheffield Section for a number of years : he was also a member of the Iron and Steel Institute.

RECENT DEVELOPMENTS

MATERIALS : PROCESSES : EQUIPMENT

A New Bright Nickel Plating Process

A NEW bright nickel plating process now available in this country was introduced in the United States a few months ago, and sufficient practical data has now been accumulated to confirm its important advantages. Termed the Efco-Udylite Bright Nickel Plating Process No. 514, it is currently available through Electro-Chemical Engineering Co., Ltd., who are launching the process in the British and European markets after carrying out a series of exhaustive tests on its capabilities and potentialities. The principal advantage of the No. 514 Process when compared with the older and well-known Efco-Udylite No. 31 Process is that a solution is provided with greatly improved line filling or levelling properties, and characterised by an exceptionally wide bright plating range. An important saving in polishing and handling time becomes available, since maximum brightness is attained, and the process is particularly advantageous for recessed articles, which are notoriously difficult to plate brightly by reason of their contour.

The new solution is prepared by adding three brightening agents and one anti-pitting agent to a basic solution which is prepared and purified in accordance with a standard method. Of the three principal constituents of the basic solution, the nickel sulphate is the principal source of nickel ions; the nickel chloride enables the anodes to dissolve correctly without polarisation, and also improves the conductivity of the solution; and the boric acid content is most important for stabilising the *p*H value and for aiding brightness and ductility.

Brightener No. 41 in conjunction with Brighteners Nos. 2 RL and 3, imparts to the solution the ability to produce uniformly bright deposits, and to increase the brightness of the deposit as the thickness increases. This property, called "levelling" or "line-filling", enables the deposit to minimise the effects of small irregularities in the base metal surface, and is one of the most important advantages of this process. Finally, Non-Pitter No. 22, which is supplied in liquid form, prevents gas pitting.

A temperature of 130–150° F. (optimum 140° F.) is recommended for best overall results. The use of high temperatures permits a high average current density to be employed. The average cathode current density is 20–40 amp./sq. ft., and the anode current density is 10–30 amp./sq. ft.

A variation of Process No. 514 is available (Process No. 514H) which is particularly recommended for plating on copper-plated zinc-base die castings, where the high resistance of the solution to zinc contamination is of great importance. By using this solution it is possible to withstand a contamination of approximately nine times the amount of zinc when compared with the standard No. 514 Process. The No. 514H solution is claimed to be of great value as a general purpose solution in installations such as automatic plants, where its high permissible cathode current density permits specification plating in comparatively short process times.

Electro-Chemical Engineering Co., Ltd., Queens Road, Weybridge, Surrey.

The two hubs on the right were plated in the 514 bright nickel process, those on the left in the 31 bright nickel process.

Pressure Paint Container

ALFRED BULLOWS & SONS, LTD., have introduced a 2-gal. pressure paint container, of entirely new design and

construction. The shell, as well as the cover, is in the form of a high tensile aluminium alloy diecasting, and replaces the conventional galvanised welded mild steel shell. This shows a substantial saving in weight and, most important, gives a perfectly smooth surface both inside and out, making cleaning of the container a very simple matter. The cover is held in position by forged steel C clamps and handscrews, enabling it to be quickly and easily removed. The material feed pipe is duralumin. This means that all parts in contact with the paint are of aluminium alloy or stainless steel: there is no brass or mild steel used internally at all.

The container is available with or without a pressure

reducing valve unit, which is flange mounted on the cover and houses the shrouded pressure gauge. It has a built-in safety valve which has an easing ring, so that it is used as a blow-off valve, and is non-adjustable. The container will also be available with a galvanised mild steel shell, for use with materials corrosive to aluminium. All containers are for a maximum working pressure of 50 lb./sq. in. and are hydraulically tested to 100 lb./sq. in.

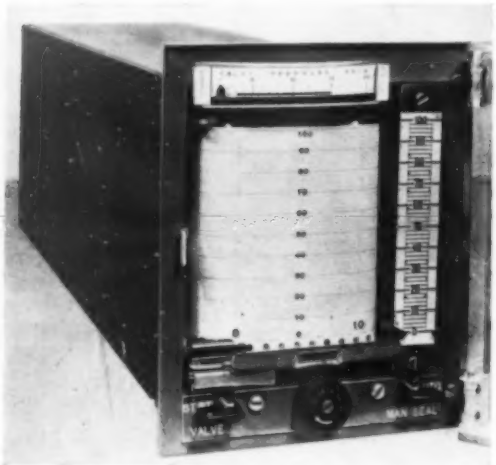
Alfred Bullows & Sons, Ltd., Long Street, Walsall, Staffs.

Tel-O-Set Miniature Instruments

MINIATURE instruments are capturing the attention of a rapidly widening industrial audience. The dimensions of these instruments are obviously important where graphic panels are required, or where panel space must be economically employed. The Tel-O-Set range of miniature instruments available from Honeywell-Brown, Ltd., offers a standard pneumatic indicator, recorder, and controller for all process variables. Separate pneumatic transmitters for most variables are within the Honeywell range. Tel-O-Set instruments are unit constructed to permit simple replacement of major sections, but unit construction is only one aspect of the 'unit' approach to modern instrumentation made possible by the introduction of these instruments. The design of future process instrumentation need only involve the selection of the required number of Tel-O-Set units.

One of the most interesting and valuable features of the new instruments is the flexible operating relationship between recorder (or indicator) and controller. A flat gasketed surface at the rear of the recorder matches up perfectly with the controller which has a single lever quick-disconnect switch. The controller can be mounted in the back of the recorder, behind the instrument panel, or at a remote location. All controller adjustments are readily accessible from the rear. Proportional and integral control actions of the Tel-O-Set controller are easily adjusted; the instrument offers a simple choice of three integral action times—slow, intermediate, and fast. Derivative control is readily added to the basic model.

A full 8-hour chart record is visible when the chassis is withdrawn; with the chassis partially or completely withdrawn, the instrument remains fully operative. A horizontal scale above the chart provides a continuous indication of control air pressure to valve even when the recorder chassis is completely removed. The location of control knobs ensures that manipulation (from front of panel) does not obscure the view of pointer or scale. Automatic chart re-roll, giving 30-day process record and daily chart tear-off are available as alternatives. Another excellent example of flexible design is the interchangeability of the recorder and indicator chassis. The need for differently coloured instrument cases is eliminated by an interchangeable bezel on the front of the instrument. The Tel-O-Set recorder requires a panel cut-out measuring only $5\frac{1}{32}$ in. $\times$ $4\frac{9}{16}$ in. This small area accommodates all that is usually visible of an instrument designed to meet the most exacting process requirements.



Honeywell-Brown, Ltd., Perivale, Middlesex.

P.V.C. Bifurcated Fans

WITH the introduction of the Tornado range of bifurcated fans to the U.K. market in 1952, by Keith Blackman, Ltd., a new design of fan was brought to bear, successfully, on the problem of industrial fume removal.

The bifurcated design of fan casing allows the easily accessible direct-driving motor to be completely isolated from, and therefore unaffected by, the fumes passing through the casing. The standard range is constructed with welded steel casings and cast aluminium-silicon alloy impellers in sizes from 10 in. to 25 in. diameter. They are normally coated with a sprayed enamel finish, but when working under more arduous conditions, additional protection is given to the internal surfaces by a rubber covering or a liquid plastic coating.

An inherent weakness in these finishes is the fact that they are only "skin deep." The slightest penetration of the otherwise perfectly protective surface results in corrosive attack of the parent metal beneath, and unrestrained corrosion radiating from that point. This difficulty has been overcome by the introduction, by Keith Blackman, of bifurcated fans with solid P.V.C. casings and impellers. No special coating has the equivalent anti-corrosive properties of solid P.V.C. material in such a wide field of chemicals. Two additional advantages of the new type are that they are quieter in operation and comparable in price with the old type. The new range is available in sizes from 10 in. to 19 in.

Keith Blackman, Ltd., Mill Mead Road, Tottenham, London, N.17.

CURRENT LITERATURE

Book Notices

RESEARCHES INTO THE WELDING OF ALUMINIUM AND ITS ALLOYS

A.D.A. Research Report No. 27. 60 pp., numerous tables and illustrations. Published by The Aluminium Development Association, 33 Grosvenor Street, London, W.1. 7s. 6d.

THE Welding Research Team of the Aluminium Development Association was constituted to investigate the reasons why certain aluminium alloys are not readily weldable and—as a result of the information so obtained—to suggest modifications to chemical composition, mode of manufacture or welding procedure which might lead to the production of good high-strength welds in these alloys. A summary of the work to date was published as A.D.A. Research Report No. 6 at the end of 1949, and over the whole period from 1944 to 1950 individual researches have been reported to learned societies and, on occasion, in the technical press. The present publication, which has been prepared by Dr. W. I. Pumphrey, constitutes a summary of the entire investigation gathered together in a form in which it was thought to be most convenient for other workers in the field, and for the many for whom the results will have practical application.

Professor A. J. Murphy, formerly Director of the Departments of Physical and Industrial Metallurgy in the University of Birmingham, where the work was carried out, contributes an appreciation of the whole research in the form of a preface. The Report is then divided into the following main sections: cracking at temperatures above the solidus; cracking at temperatures below the solidus; factors affecting weldability; temperature distribution during the welding of aluminium alloys; the development of alloys having good welding and mechanical properties; and cracking diagrams for aluminium alloys. Appendices detail (I) the cracking tests used, i.e., ring casting tests and restrained weld tests; and (II) the complete list of papers published by the Research Team.

ZINC AND LIGHT METAL DIE CASTING

Report of Technical Mission to U.S.A. 152 pp., numerous tables and illustrations. Published by The European Productivity Agency of The Organisation for European Economic Co-operation and available from H.M. Stationery Office. 12s. 6d.

THIS publication contains the observations and recommendations of the members of Tecaid Mission No. 155, which visited the United States in the spring of 1954 under the auspices of the Organisation for European Economic Co-operation and the American Foreign Operations Administration. The team was divided into four groups, to study particular aspects of die casting, and each group had its own itinerary, only occasional visits being made by the Mission as a whole. In all, just over fifty foundries, finishing plants, machine makers, alloy makers and research laboratories were visited, of which thirty were die casters, from the smallest to the largest.

The chapters in the report cover virtually the same ground as the four groups: die casting machines, die design and die construction; metallurgy; foundry practice; and finishing die castings. There is also a short chapter on management and labour relations. Five annexes deal with: The American Die Casting Institute; typical American applications of die castings; the impact strength of commercial zinc die castings; list of firms visited; and list of members of the Mission. Recommendations are made on such aspects as alloys; design of castings and dies; dies; die casting machines; temperature control; die lubricants; inspection; handling; trimming; machining; polishing; and cleaning. In considering these recommendations it should be borne in mind that the report is for European readers and some of the suggestions made may already be practised in certain countries.

FUEL CONSERVATION AND PRODUCTIVITY

24 pp., B.P.C. Action Pamphlet No. 5. Published by the British Productivity Council, 21 Tothill Street, London, S.W.1. 9d.

IN this pamphlet, the British Productivity Council sets out the main points which managements need to look at if they are to make sure that their fuel costs are cut to the minimum. Many of the methods described for saving can be installed with very small capital expenditure. The pamphlets give notes on the advisory services available to industry from the National Industrial Fuel Efficiency Service, and from the Federation of British Industries; and on the Government Loan Scheme, which is designed to help firms to finance the installation of equipment to secure more economical use of fuel.

Trade Publications

The Bonderizer for January 1956, published by the Metal Finishing Division of the Pyrene Co., Ltd., Great West Road, Brentford, Middlesex, features an article describing the application of Bonderizing in the manufacture of British Railways' standard passenger coaches. Other features describe the use of Bonderizing and Pyluminizing in the manufacture of Belling electric heaters and the Bonderizing of the Plus Fordham wheeled golf caddy.

AN article explaining the considerations affecting the use of high or mains frequency induction heating, with special emphasis on the latter, is featured in the December 1955 issue of *The Wild-Barfield Heat Treatment Journal*. The contents also include a critical appraisal of the development of the nitriding process and a description of a new compact 40 kW high frequency induction heating equipment.

FIFTY years ago the first trial melts were made of an alloy of nickel and copper, which it was then believed might develop into a useful engineering material. Performance tests justified this belief and under the name of Monel the alloy was subsequently accepted for many purposes where strength and corrosion resistance were required. A special issue of *Wiggin Nickel Alloys* (No. 37) marks the end of the first half-century of Monel, and contains articles which show how Monel still solves

many of the engineering problems of today. Copies may be obtained from Henry Wiggin & Co., Ltd., Wiggin Street, Birmingham, 16.

To whatever section of the British steel industry one turns, the story is one of plant development and increasing output, and in "Dorman Long 1955 Illustrated" a brief account is presented of the progress made by this important Tees-side firm. Throughout the year the building of new coke ovens, blast furnaces, and the cogging and medium section mills at Cleveland Works, and of the great new universal beam mill at Lackenby has proceeded, and new units have been installed at Clarence for dealing with the greater amount of tar resulting from the increased coking capacity. These schemes have made heavy demands on the structural engineering departments, but they have, nevertheless, been able to undertake many projects for customers in this country and abroad.

A SERIES of industrial technical bulletins has been started by Vacuum Oil Co., Ltd., Westminster, London, S.W.1 with the issue of the first six. No. 1 deals with S/V Ceremuls—homogeneous dispersions of uniformly fine particles of petroleum waxes held in dispersion by carefully chosen emulsifiers; No. 2 with industrial petrolatums or petroleum jellies; No. 3 with Gargoyle Grease BRB No. 1 and ball and roller bearing lubrication; No. 4 with the Gargoyle Compounds and enclosed gear lubrication; No. 5 with oils for the machine shop; and No. 6 with Gargoyle Dorcias and open gear lubrication.

IN *Foseco Foundry Practice*, No. 123, an account is given of an investigation of a porous gun metal ring casting and further recommendations are made for overcoming shrinkage porosity in a pressure die cast aluminium washing machine pulsator, whose investigation was featured in an earlier issue. The present issue also contains features on bronze and gun metals, taper on patterns, trouble-free cupola slagging and loose-joint making.

THE Winter 1955 issue of *Torch*, a quarterly technical bulletin issued by British Oxygen Gases, Ltd., contains features dealing with such a variety of subjects as oxy-hydrogen underwater cutting; the welding of copper; Argonarc welding equipment; glass fibre as a new constructional material, and Donald Campbell's "Blue Bird." In the series "British Oxygen in Industry," railways are featured in this issue. Copies may be obtained from Bridgewater House, Cleveland Row, St. James's, London, S.W.1.

WE have received from Hilger & Watts, Ltd., 98 St. Pancras Way, Camden Road, London, N.W.1, a leaflet describing the Hilger-Jace Carbon Electrode Shaper, made under licence from the Jarrell-Ash Co., of the U.S.A. This equipment can be used for controlling, pointing and undercutting electrodes to a variety of shapes.

VOL. 1, No. 5, of *Stainless Steel Review* appeared as a Christmas Number showing a range of items of kitchen and table ware made from stainless steel. Copies may be obtained from British Electro Metallurgical Company, a Division of Union Carbide, Ltd., Wincobank, Sheffield.

"The Beginning of an Adventure" is the title of a new publication issued by High Duty Alloys, Ltd., Slough, Bucks., which gives particulars of the H.D.A. Apprenticeship Scheme open to any boy between the ages of 15 and 16 who is qualified to enter the Preliminary Year of the Ordinary National Certificate Course. The title has been chosen because the Company feels that there is probably no other undertaking to-day that offers so much scope, for those with an adventurous spirit, as the aluminium industry.

THE selenium dry plate pattern static type rectifiers are today being increasingly used in preference to rotary generators, and in a recent publication particulars are given of the range manufactured by The General Electric Co., Ltd., Magnet House, Kingsway, London, W.C.2.

PUBLICATION CH 398, recently issued by Hilger & Watts, Ltd., details the results of analyses of aluminium alloys undertaken with the medium quartz spectrograph and its direct reading attachment. It gives working curves for the elements most likely to be encountered and will be found impressive by spectrochemical analysts. At the end of the booklet a few curves showing the capabilities of the apparatus for the analysis of magnesium alloys are given. Copies can be obtained from 98 St. Pancras Way, Camden Road, London, N.W.1.

THE first issue of *Mobil Industrial Review*, published simultaneously by Mobil Oil Co., Ltd., Caxton House, Westminster, London, S.W.1, and by Mobil associates on the Continent, is devoted to the diesel engine. Following an historical introduction, the principle and advantages of the engine are discussed, and the European diesel industry surveyed. The final section deals with lubricants for diesel engines.

A NEW leaflet from Gibbons Brothers, Ltd., Dudley, deals with Gibbons Thermo (patent) Continuous Furnaces, the licence for the building of which in Great Britain and other countries has been granted to the Company by Messrs. "OFU" Ofenbau-Union, G.m.b.H., Dusseldorf. Advantages in respect of control, economy and availability are claimed for this type of furnace.

THE December 1955 issue of *Marconi Instrumentation* features a preview of 25 new instruments which are to appear in the Marconi Electronic Measurement Catalogue for 1956. Articles are also included on a new resistance-capacitance oscillator, an alignment oscilloscope, and a new UHF and SHF signal generator. Copies may be obtained from Marconi Instruments, Ltd., St. Albans, Herts.

THE continuous galvanising plant installed at The Firth Co., Ltd., Warrington, is described in a reprint recently issued by the Incandescent Heat Co., Ltd., Smethwick. The installation caters for the complete process, from de-winding prior to lead bath annealing to re-winding after galvanising.

A NEW pamphlet issued by Crompton-Parkinson, Ltd., Crompton House, Aldwych, London, W.C.2, describes the part that C.P. electrical equipment and instruments play in technical educational establishments throughout the world. Novel ideas and methods of mounting and adapting instruments and equipment for test purposes in laboratories and demonstration rooms are clearly illustrated.

VARIOUS aspects of ultrasonic flaw detection are discussed in No. 2 of *Kelvin Hughes Industrial Review*, including the depth gauge and the automatic scanning technique. Other articles deal with electronic temperature control in the razor blade industry, boiler house instrumentation and colour fastness testing. Copies may be obtained from Kelvin & Hughes (Industrial), Ltd., 2, Caxton Street, London, S.W.1.

LABORATORY METHODS
MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS

MARCH, 1956 Vol. LIII, No. 317

A Semi-Micro Method for the Determination of Carbon in Iron and Steel

By P. H. Scholes

Metallurgy (General) Division, The British Iron and Steel Research Association

An apparatus for the estimation of the carbon content of ferrous alloys based on the micro combustion technique for the determination of carbon and hydrogen in organic materials is described. A detailed account of the operational procedure is given, together with typical results for standard steels.

SEMI-MICRO analytical methods should not be regarded as substitutes for the usual methods of analysis. There can be no purpose in employing semi-micro techniques, which demand the greatest possible care on the part of the operator, when the quantity of material is sufficient for analysis by macro methods. Microchemical techniques prove invaluable, however, when the chemist has available the minimum amount of material for analysis. During the past 15 years, several comprehensive schemes have been published for the complete analysis of samples of ferrous alloys weighing only a few tenths of a gram.[1, 2, 3] Each author has given special attention to the determination of carbon, and has shown that the apparatus for its determination in organic material[4, 5] may be modified for use with iron-base alloys.

Since carbon is of the greatest importance where the metallurgical properties of steel and other iron-base alloys are concerned, it often becomes imperative to employ a semi-micro method when only very small samples can be made available. Examples encountered in the author's laboratory include analysis of carburised iron wires, examination of large carbide segregates in high speed steel, the analysis of ferrous corrosion products, an investigation into heterogeneity of wrought iron, and the routine analysis of small scale melts of ferrous alloys. Reference to the literature provides many other examples of the application of semi-micro combustion techniques, for instance :—

(1) The investigation of complaints resulting from the failure of small ordnance parts and ball bearings during service.[3]
(2) The analysis of carbides after anodic decomposition of highly alloyed steels.[6]
(3) The study of segregation in 80-20 Nickel-chromium alloys.[7]

The principle of the method described is essentially the same as that of the British Standard method for carbon in steel.[8] The carbon is completely oxidised to give carbon dioxide by combustion at an elevated temperature in a stream of purified oxygen. Sulphur gases and water vapour are removed from the subsequent stream of gas and the carbon dioxide absorbed in soda asbestos contained in a micro absorption tube. The increase in weight of the tube is obtained by using a sensitive micro-balance, and is a measure of the percentage carbon in the alloy.

This paper describes in detail an apparatus for the determination of carbon in ferrous materials using samples weighing 0·01–0·05 g. An account of the operational procedure is also given. The method is based on that described by Vaughan and Whalley.[3]

Sampling

No fixed procedure can be laid down for sampling, as this will depend largely on the shape of the specimen and on the purpose of the test. Small lumps or fragments of brittle material may readily be crushed in a hardened steel mortar. Short lengths of wire and rod should be flattened first in a small percussion mortar, and then clipped into small pieces. For the examination of variation in surface composition, the wide range of drills and milling tools employed by the dentist and watchmaker can be helpful: the test piece may be drilled at short intervals across the surface or, as an alternative, thin layers may be removed by means of a small milling machine.

After sampling, the drillings or millings are examined under a hand lens and obvious impurities rejected. Any grease or oil which may have contaminated the sample during machining must be removed by washing with pure ether. The sample is dried at 105° C. in an air oven, and then heated to approximately 180° C. to remove the last traces of surface-absorbed ether. Finally, it is transferred to a glass stoppered sample tube.

Apparatus

The combustion furnace was designed in conjunction with The Amalgams Co., Ltd.,* for use with Morgan Triangle "H" porcelain combustion tubes (Type T6370—30 cm. long × 1 cm. diameter). Two tubes are

* Attercliffe Road, Sheffield, 4.

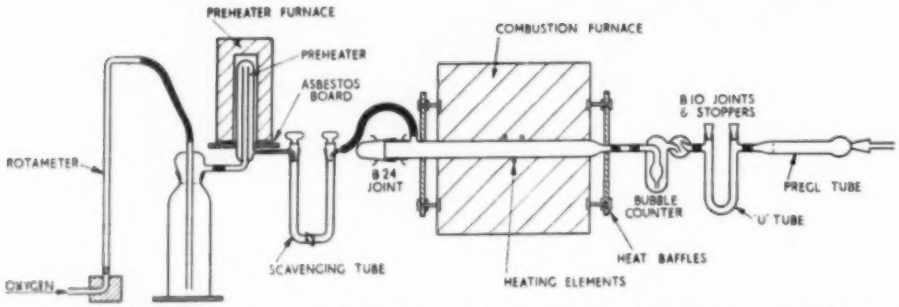


Fig. 1.—Diagrammatic arrangement of the apparatus for the microchemical determination of carbon in iron and steel.

fixed in position in the centre of the furnace casing and are heated by three silicon carbide elements positioned at right angles to the combustion tubes. The elements are connected in series and heated by applying a potential of 80–130 volts. This produces a hot zone 5 cm. in length. A temperature of 1,300° C. can be obtained in about two hours, and the furnace has been satisfactorily operated at temperatures up to 1,450° C. To protect the rubber connections at each end of the combustion tube from undue heat radiation it has been found necessary to fix asbestos board heat baffles between casing and connection. The combustion furnace may also be used for the semi-micro determination of sulphur by the potassium iodide-iodate method.[3] It is extremely simple in design and avoids the capital expenditure required for platinum-wound combustion furnaces.

Combustion boats* made from aluminous porcelain are available in two sizes: "000"—16 × 4 × 3 mm., suitable for 10–50 mg. sample weights, and "00"—29 × 5 × 5 mm., suitable for 50–200 mg. sample weights.

To measure the increase in weight of the absorption tube, which is of the order of 0·1–2·5 mg. for steel samples, it is necessary to install an accurate micro-balance, sensitive to 1 μg. Before installation, careful consideration must be given to the most suitable location and the reader is referred to the many papers on the subject[9, 10, 11]. A useful summary of the conditions required for the satisfactory operation of a micro-balance is provided by Pigott.[2]

The air-damped micro-balance in use in the author's laboratory is mounted on a heavy slate slab, 2 ft. × 5 ft. × 2 in., fixed by cantilevers to an inner wall: this type of mounting has completely eliminated troubles arising from vibration. Direct sunlight is avoided by the use of sunblinds, and dust is excluded by enclosure in a glass panelled case. Temperature control in the laboratory is not ideal, and difficulties are encountered during conditions of extreme humidity.

The Combustion Train†

Oxygen is supplied through a gas regulating valve to a flowmeter of the Rotameter type. The latter is connected to a 250 ml. Dreschel bottle, fitted with a ground glass joint, which provides a reservoir of oxygen for rapid consumption during combustion. Carbon monoxide and hydrocarbons in the oxygen are removed by a purification unit; this consists of a preheater containing platinised asbestos at a temperature of 500° C. and a scavenging tube containing magnesium perchlorate and soda asbestos to absorb the carbon dioxide and water produced. The scavenging tube is connected to the side arm of one of the combustion tubes; the mouth of the latter is closed by a Pyrex B24 cone and socket joint. The male joint is terminated 2 cm. from the shoulder and fitted over the combustion tube end, gas tightness being achieved by means of a rubber sleeve circumscribing the end of the combustion tube and fitting inside the male joint: the female joint is sealed off as near the shoulder as practicable, and the two parts are kept in close contact during combustion by small springs.

The reduced end of the combustion tube is connected via a 6 in. length of capillary tubing to a Pregl bubble counter and U-tube fitted with a spray trap. The bubble counter contains 2 ml. of chromic-sulphuric acid[7] to remove sulphur gases, and the U-tube is packed with small pieces of granulated zinc, to absorb acid spray, followed by magnesium perchlorate to remove water vapour from the gas stream. The Pregl absorption tube is packed with 10–14 mesh soda asbestos with a small quantity of magnesium perchlorate at each end.

The reagents are separated and held in place with small plugs of cotton wool in the scavenging and absorption tubes, and with plugs of glass wool in the U-tube, and all glass stoppers are sealed in place with Krönig's glass cement. Artificially-aged rubber tubing, which has been treated to remove compounds which might enter the gas stream as impurities, is used throughout, and all connections are made glass-to-glass as far as possible.

Procedure

Weigh out 50·00 mg. of sample and transfer to a size "000" combustion boat. The sample weight may be adjusted between 10 and 50 mg., depending upon the quantity of material available and the anticipated carbon content: the accuracy of the method decreases as the sample weight is reduced, and it is not always possible to obtain reliable figures if less than 10 mg. is available. With carbon contents of less than 0·05%, the sample weight may be increased up to 200 mg. The use of fluxes to assist combustion has been found to be unnecessary for the majority of steels, but complete combustion of stainless and other highly alloyed steels can be facilitated by the addition of several milligrams of powdered tin, and by operation at a temperature of 1,350–1,400° C. For exceptionally refractory materials, such as high chromium alloys, it may be necessary to mix with an equivalent weight of low carbon iron to act as an accelerator. The blank value the of fluxing material must be determined and deducted from the weight of carbon dioxide found in the test sample.

Wipe the Pregl tube with a damp cloth and carefully clean the inlet and outlet tubes with cotton wool. Polish the tube with a dry chamois leather and counter-

* Supplied by Alpolain Industries, Ltd., Dalewood Road, Sheffield, 8.
† See Figs. 1 and 2.

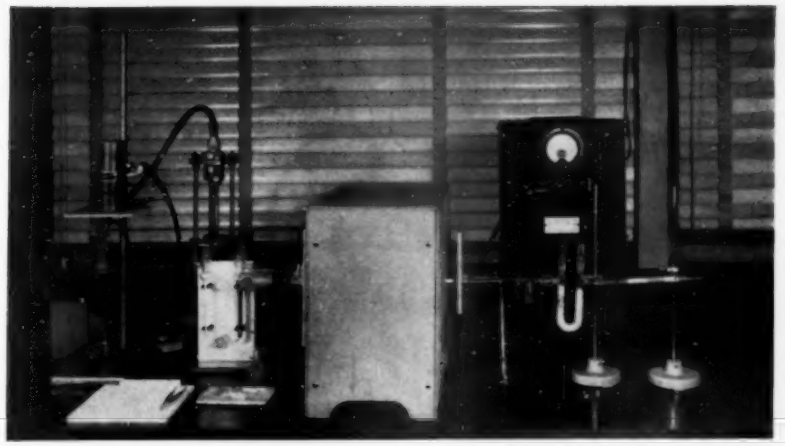


Fig. 2.—General view of the apparatus.

poise against a 10 ml. flask containing glass beads. After this initial cleaning treatment, the fingers must not come into contact with the tube, which should at all times be handled with a chamois leather.

Stabilise the temperature of the combustion tube at 1,300° C. and pass oxygen at a rate of 10 ml./min. for at least one hour. Then, in order to saturate the rubber tubing with carbon dioxide, ignite about 100 mg. of carbon steel contained in a size "00" boat. Pass oxygen for 15 minutes, disconnect the Pregl tube and weigh. Re-connect and weigh again at intervals of 10–12 minutes, until the tube reaches a sensibly constant weight, i.e., not varying by more than 15 μg. between each weighing. Introduce the first test sample into the hot zone by means of a 15 cm. nickel pusher rod, close the glass cap joint and, if necessary, slightly increase the rate of oxygen flow until combustion appears to be complete. Pass oxygen at 10 ml./min. for a further 10–12 minutes, weigh the absorption tube, and calculate the percentage carbon content from the increase in weight due to carbon dioxide absorption.

$$\text{Carbon percentage} = \frac{\text{Weight of carbon dioxide in mg.} \times 27{\cdot}29}{\text{Sample weight in mg.}}$$

For routine analysis, the Pregl tube should be weighed immediately upon placing on the balance pan stirrups, but for extreme precision, the tube should be allowed to attain equilibrium with the atmosphere inside the balance case: this may take from 10 to 20 minutes. When this technique is utilised[1], the procedure may be speeded up by using two absorption tubes, since at the end of one test run the furnace can immediately be used for the next sample.

Reproducibility

To give some indication of the reproducibility which may be expected from semi-micro combustion techniques, a series of results for the carbon content of seven British Chemical Standard samples and one standard steel supplied by the Bragg Laboratory is presented in Table I.

TABLE I.

B.C.S. No.	Accepted Carbon Content (%)	Combustion Temperature (° C.)	Weight of Sample (mg.)	Number of Determinations	Mean Carbon Content (%)	Average Deviation (%C.)
152—Carbon Steel ..	0·114	1,300	100	8	0·11	± 0·01
152—Carbon Steel ..	0·114	1,300	50	6	0·11	± 0·02
159—Carbon Steel ..	0·525	1,300	50	8	0·53	± 0·02
163—Carbon Steel ..	1·203	1,300	50	8	1·21	± 0·03
163—Carbon Steel ..	1·203	1,300	20–25	6	1·23	± 0·05
235—Stainless Steel ..	0·14	1,350	50	6	0·13	± 0·02
236—Cast Iron	3·07	1,300	20	6	3·05	± 0·1
204—Ferro-Chromium	5·09	1,400	10	3	5·06	—
263—Low Carbon Steel	0·047	1,300	100	6	0·05	± 0·01
Carbon Steel "H" ..	0·464	1,300	40–60	20	0·46	± 0·02

Conclusions

Carbon may be determined in ferrous materials by the combustion of samples weighing 0·05 g. or less with an accuracy approaching that obtainable when the conventional British Standard Method is used.

Acknowledgments

The author acknowledges with grateful thanks the many valuable suggestions made by Mr. W. R. Nall of the Bragg Laboratory, Naval Ordnance Inspection Department. Thanks are also expressed to Mr. K. Speight and Mr. E. Ineson for helpful criticism, and to Mr. J. F. Burgess who constructed the glass apparatus. The paper is published by permission of the British Iron and Steel Research Association.

REFERENCES.

1 Klinger, P., Koch, W., and Blaschayk, G., *Angewandte Chemie*, **53**, 537–549 (November 23rd, 1940).
2 Pigott, E. C., "Ferrous Analysis—Modern Theory and Practice," 1953, Chapman and Hall.
3 Vaughan, E. J., and Whalley, C., *J.I.S.I.*, **155**, 535–562 (April, 1947).
4 Belcher, R., and Godbert, A. L., "Semi-Micro Quantitative Organic Analysis," 1945, Longmans, Green & Co., Ltd.
5 British Standard 1428 : Part A1 : 1950—Carbon and Hydrogen Combustion Train (Pregl Type).
6 Pemberton, R., *Analyst*, **77**, 287–292 (1952).
7 Balis, E. W., Liebhafsky, H. A., and Winslow, E. H., *Ind. Eng. Chem., Anal. Ed.*, **15**, 68–69 (1943).
8 British Standard 1121 : Part 11 : 1948—Carbon in steel and low-carbon ferro-chromium.
9 Emich and Schneider, "Microchemical Manual," 1932, Wiley & Sons.
10 Corner and Hunter, *Analyst*, **66**, 149 (1941).
11 Kirner, *Ind. Eng. Chem., Anal. Ed.*, **9**, 300 (1937).

Jessop-Heppenstall Die Block Agreement

THE HEPPENSTALL COMPANY of Pittsburgh, U.S.A., manufacturers of die blocks, has recently entered into an agreement with William Jessop & Sons, Ltd., Sheffield, under which Jessops will manufacture Hardtem die blocks in the United Kingdom in accordance with the Heppenstall technique, and will sell the product with the backing of the reputations of the two companies. The whole of the technical knowledge and experience of the Heppenstall Company in this line, in which they have specialised for so long, will be available to Jessops. Users of die blocks will be interested in this announcement, as it provides an additional source of supply in the United Kingdom. Enquiries for Jessop-Heppenstall die blocks should be addressed to William Jessop & Sons Ltd., Sheffield, 9.

Liquid-Liquid Extraction Procedures in Inorganic Analysis

A Review of Practical Applications with Particular Reference to Metallurgical Analysis

By T. S. West, B.Sc., Ph.D., A.R.I.C.
Department of Chemistry, University of Birmingham

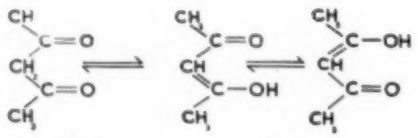
The growing complexity of modern materials has led to difficulties in their chemical analysis resulting from the increasing multiplicity of other substances accompanying the constituent to be determined. The development of new separation methods has made possible the continued use of classical analytical procedures in the face of increasing competition from physical methods, and in the present series of articles the author surveys liquid-liquid solvent extraction techniques in inorganic analysis, with particular reference to metallurgical analysis. In the second of the series, the author discusses the extraction of Group II metals.

(*continued from page 96 of the February issue of* METALLURGIA)

EXTRACTION OF GROUP IIa METALS (Be, Mg, Ca, Sr, Ba)

Beryllium

IN the course of this survey, no account could be found of the solvent extraction of beryllium as an inorganic compound, apart from a report by Fischer and Bock[42] that more than 50% of beryllium is extracted from 0·5 N hydrochloric acid containing 53% ammonium thiocyanate by an equal volume of diethyl ether. Aluminium, iron, indium and scandium are co-extracted with the beryllium. Indeed, with the exception of the 1, 3 diketones, none of the common chelating agents, e.g., oxine, dithizone, etc., appear to be capable of extracting this metal from aqueous solutions. The simplest member of the 1, 3 diketone group is acetyl acetone.



This compound reacts with beryllium in the enolic form to give an inner complex compound in which the beryllium replaces the enolic hydrogen atom and is co-ordinately bound to the keto oxygen, thus forming a six-membered ring. The chelate is practically insoluble in water, but readily dissolves in benzene and similar solvents. In an examination of the determination of microgram amounts of beryllium, Adam, Booth and Strickland[24] used the extraction of this chelate into chloroform from aqueous solutions at *p*H 6–10. Of the common metals, uranium, lead, silver, cerium, copper, molybdenum, zinc, chromium, manganese, the alkaline earths and the alkali metals do not interfere, but aluminium and ferric iron interfere rather seriously. The common anions such as sulphate, nitrate, chloride, perchlorate, fluoride, and phosphate did not markedly influence the extraction, but citrate interfered and also large amounts of acetate. Complete recovery of 10 μg. amounts of beryllium in 50 ml. of solution containing 100 μg. of iron and aluminium was obtained when these metals were complexed in the aqueous phase by ethyenediamine tetra-acetate. Toribara and Sherman[25] compared the efficacy of acetyl acetone and another 1, 3 diketone, thenoyltrifluoroacetone, as chelating agents for the extraction of beryllium from aqueous solution. Using benzene as the extracting solvent, they found that, whereas both diketones were very effective in removing beryllium, the acetyl acetonate was more readily decomposed by acid, as evidenced by the complete back-extraction of beryllium into an aqueous phase when the separated benzene layer was equilibrated with 5*N* hydrochloric acid. The thenoyltrifluoroacetone was so stable that back-extraction was complete only after 80 hours, even when concentrated hydrochloric acid was used to break up the chelate.

The conditions proposed by various authors for the use of acetyl acetone in the extraction of beryllium vary considerably. In the presence of complexing anions, it appears that as low a *p*H as possible should be used. This minimises the complexing action of these ions, whilst still allowing the 1, 3 diketone compound to be formed (too low a *p*H will, of course, also inhibit its formation). At high *p*H values, the ionisation of the acetyl acetone favours its solubility in the aqueous phase and discourages extraction of the beryllium. Toribara and Sherman favoured extraction at *p*H 4–5, and recommended stirring the aqueous phase with acetyl acetone for 5 minutes before adding benzene. They found that this procedure was superior to direct extraction with a solution of acetyl acetone in benzene.

On the other hand, Bolomey and Wish[26] compared acetyl acetone and thenoyltrifluoroacetone (T.T.A.) and found in favour of the latter as a solvent extracting reagent for the isolation and purification of carrier free radio-beryllium. Bolomey and Wish indicate that the advantages of T.T.A. are that it forms a stronger complex which is much more stable at low *p*H ranges, and

that it is much less soluble in neutral and acid solutions. From other points of view, T.T.A. has the advantage that the chelate it forms is non-volatile, although it may be sublimed under high vacuum. At *p*H values greater than six, the extraction of beryllium is rapid, whilst at *p*H 4 it is slow. The optimum *p*H for the extraction of the beryllium-T.T.A. complex is in the neighbourhood of neutrality. Ferric iron is extracted slowly at *p*H 6·4 and more rapidly at *p*H 4·5. The optimum *p*H for its extraction lies within the range 2–3. Aluminium extracts rapidly at *p*H 5·5 and slowly at *p*H 3·4, while divalent copper extracts rapidly at the latter *p*H.

In back-extracting various metal ions from a 0·01M solution of T.T.A. in benzene with concentrated hydrochloric acid, it was found that iron, copper, strontium, yttrium, calcium, and zinc, etc., were back-extracted within 15 minutes. Aluminium required 6 hours. About 40% of the beryllium is returned to the aqueous phase in 6 hours, but, as stated previously, 80 hours are necessary for complete recovery.

The Alkaline Earths

The extraction of alkaline earth salts from aqueous solution is a difficult matter, although their extraction from the solid state into water-immiscible solvents such as amyl alcohol, etc., is well known.[27] The alkaline earths form few strongly bound chelates, with the exception of those with the complexone group, particularly ethylenediamine tetra-acetic acid. Unfortunately, these complexes are not soluble to any marked extent in organic solvents. Recent reports in the literature suggest that it may well be possible to extract these metals as their chelate compounds with certain 1, 3 diketones. Thus, for example, Broido[28] has reported on the solvent extraction of trivalent scandium from a calcium radioisotope, Ca45. The equilibrium constants for the extraction of the two T.T.A. complexes are: $K_{Sc} = 0{\cdot}9$ and $K_{Ca} = 1 \times 10^{-12}$, so that the separation of the two is a relatively simple matter. The scandium is completely extracted at *p*H values as low as 1·5, whilst no appreciable extraction of calcium occurs below *p*H 8. Whilst Broido was primarily concerned with the extraction of scandium itself, it would appear that, using T.T.A. at *p*H values greater than 8, removal of calcium from aqueous solution may be possible.

Magnesium chloride is well known to be soluble in amyl alcohol, alcoholic ether, etc.,[29] but no trace of papers dealing specifically with the extraction of magnesium could be found. Magnesium may not be extracted with oxine, dithizone or cupferron, and only 0·02% of magnesium is extracted by diethyl ether from an acid solution containing ammonium thiocyanate.[42]

EXTRACTION OF GROUP IIb METALS (Zn, Cd, Hg)

Zinc

Under the conditions used for the ether extraction of iron from chloride solution, only minute amounts of zinc are extracted. Similarly, under the conditions favouring the extraction of nitrates into diethyl ether, virtually no zinc is removed. On the other hand, one inorganic salt of zinc which extracts fairly easily is the thiocyanate. Moderate extraction of zinc by diethyl ether is also possible from hydriodic acid solution, but the distribution coefficient is not very favourable, extraction being of the order of 10% in 7N acid[36] and 30% in 1·5N acid[38].

Extraction of zinc is much more frequently met with after chelate formation, and indeed the first reported study of the solvent extraction of a metal by means of a chelating agent was on the extraction of zinc with dithizone. Kolthoff and Sandell[30] derived the relationship:

$$D_{Zn\ (O/W)} = K_{Zn} \frac{(H\ Dz_{(O)})^2}{(H^+_{(W)})^2}$$

where $D_{Zn\ (O/W)}$ is the distribution factor, K_{Zn} the formation constant, $HDz_{(O)}$ the concentration of dithizone in the organic solvent, and $H^+_{(W)}$ is the hydrogen ion concentration in the aqueous phase.

This was subsequently expanded by Irving and Williams[31] to provide a more accurate equation. It may be seen, however, that the extraction is favoured by increasing the dithizone concentration and lowering the hydrogen ion concentration. The equation does not provide for the formation of hydrolysis products at higher *p*H values. Cowling and Miller[32] reported that the extraction of zinc dithizonate is complete at *p*H 8·9 with carbon tetrachloride as solvent. These authors used diethyldithiocarbamate in conjunction with the dithizone, because several other metals reacted with the dithizone, forming extractable coloured compounds which interfered with the colorimetric determination of the zinc. Under these conditions, the zinc was apparently completely extracted, although some of it was present in the organic layer as the carbamate complex. Sandell[29] favours the use of carbon tetrachloride as solvent. Zinc is completely back-extracted into the aqueous phase, when the organic layer is equilibrated with 0·01–0·02N mineral acid. Metals such as lead, cadmium and bismuth are back extracted with the zinc, but cobalt and copper remain in the carbon tetrachloride layer, since their dithizonates are less easily decomposed by acid. Fischer and Leopoldi[33] used thiosulphate in the *p*H range 4–5·5 to prevent the extraction of copper, mercury, silver, gold, bismuth, lead and cadmium along with the zinc. Potassium cyanide suppresses the interference of nickel and cobalt.

Martin[34] has examined the extraction of zinc as its chelates with 2, napthylthiocarbazone and diethyldithiocarbamate. Using 50 μg. amounts of zinc, and chloroform as solvent, he reported that with naphthylthiocarbazone extraction was virtually complete in the *p*H range 7·5–10, whilst diethyldithiocarbamate gave complete removal from *p*H 6–9. At *p*H 9·8 extraction was negligible. Two to three extractions of one minute duration sufficed to ensure complete extraction of the zinc in either case. Baudisch and Furst[35] reported that the compound formed between cupferron and zinc is readily soluble in ether, but no information as to the feasibility of extraction is available. Zinc is also extractable as its oxinate, using solvents such as chloroform.

Cadmium

Like zinc, cadmium is scarcely extracted to any measurable extent by ether from hydrochloric or nitric acid, but can be extracted as its thiocyanate. Kithara[36] has shown that cadmium is completely extracted from 6·9N hydriodic acid by diethyl ether under conditions which also favour complete extraction of mercury, tin, and antimony and partial extraction of bismuth, zinc, and indium. The same author reported that the fluoride is not extracted from hydrofluoric acid solution,[37] whilst Irving and Rossotti,[38] using slightly different conditions, reported complete extraction of cadmium and tin[II] by

ether from 1·5N sulphuric acid containing excess potassium iodide. It is interesting to note that, under the conditions employed by the latter authors, some 30% extraction of zinc occurred as opposed to the 10% reported by Kitahara from 6·9N acid, and one may speculate that this figure might be considerably improved at acidities less than 1N. The extraction of cadmium iodide from 5% hydrochloric acid containing potassium iodide using methyl isopropyl ketone has been reported by West and Carlton.[40] Cadmium is frequently extracted as its chelate compound with dithizone. Saltzman[39] has recently proposed an improved extraction procedure for the dithizonate: it involves extraction by chloroform from an alkaline medium containing cyanide, and stripping the cadmium from the extract with tartaric acid. The method is said to be suitable for 100 μg samples of cadmium in solutions containing 5–10 mg. of interfering metals. Sandell[29] indicates that cadmium dithizonate in carbon tetrachloride is easily decomposed by shaking with 0·01N hydrochloric acid, thus effecting a separation from copper, mercury, silver, etc., whose dithizonates are scarcely attacked by the dilute mineral acid. In this way, a satisfactory separation from cobalt may be obtained, but nickel tends to back-extract with cadmium. On the other hand, cadmium dithizonate can be extracted from even 1N alkali solution, thus giving a separation from lead, zinc, and bismuth. Copper, silver, mercury, cobalt, and nickel are also extracted from alkaline solution, but, as mentioned previously, with the exception of nickel these remain in the organic phase when this is treated with dilute mineral acid. Cadmium dithizonate has only a limited solubility in carbon tetrachloride: in chloroform solution it is much more soluble and also more stable.

Cadmium pyridine thiocyanate may be extracted from aqueous solution by chloroform. The method is particularly valuable for the separation of cadmium from silver, mercury, and cuprous copper. The extraction is usually carried out with a solution of pyridine in chloroform from an aqueous solution buffered at *p*H 5 with sodium acetate and containing an excess of ammonium thiocyanate. Cadmium may not be extracted as its cupferrate[17] but can readily be removed by oxine in chloroform.

Mercury

Mercury is not extracted from hydrochloric acid solution by diethyl ether, but small amounts (4–5%) are extracted from 50% nitric acid by the same solvent. Quantitative extraction of mercuric mercury takes place from iodide solutions, however. Thus Kitahara[36] reported complete extraction of mercury by diethyl ether from 6·9N hydriodic acid, and using an acidity of 1·5N, Irving and Rossotti[38] reported approximately 33% removal. West and Carlton,[40] primarily concerned with the extraction of lead iodide from 0·005N hydrochloric acid containing potassium iodide, observed that mercury was partially extracted by methyl isopropyl ketone, but were able to overcome the interference by a preliminary extraction of mercuric thiocyanate with the same solvent.

Furman[17] and his co-workers state that the compound formed by mercurous mercury and cupferron is insoluble in organic solvents, while the mercuric compound is soluble in benzene and chloroform. Morrison[41] indicates that fair extraction of mercury may be obtained using cupferron. Mercury can be extracted from fairly strong mineral acid solution—*ca* 1N—by dithizone and chloroform. Under such conditions, lead, cadmium, zinc, and nickel are not extracted. A partial separation from copper is also possible, but it is better to carry out a preliminary extraction with dithizone from a solution containing bromide or iodide, since these ions complex the mercury in aqueous solution. Mercury can subsequently be extracted if the solution is basified. A separation may be obtained from silver by extracting both metals and then equilibrating the extract with a dilute solution of thiocyanate or chloride. This procedure withdraws silver from the organic layer without appreciable loss of mercury, provided the acidity is not too high. These solutions of mercuric dithizonate are orange coloured, but when exposed to strong light, the colour changes to green.[29] The colour change reverses when the solution is placed in the shade again.

Without giving any details of the actual procedure, Willard and Perkins[42] state that the complex chlorides formed by reaction of tetraphenylphosphonium chloride and tetraphenylstibonium chloride with mercuric chloride may be extracted from aqueous solution by chloroform. Stannic tin and cadmium are extracted similarly along with anions such as perchlorate, permanganate, perrhenate, pertechnetate, periodate, and fluoborate. It would appear that the solvent extraction may operate quite favourably at acidities up to 1·0N except that free nitric acid must be neutralised.

REFERENCES

24 Adam, J. A., Booth, E. and Strickland, J. D. H., *Anal. Chim. Acta.*, 1952, **6**, 462.
25 Toribara, T. Y. and Sherman, R. E. *Anal. Chem.*, 1953, **25**, 1594.
26 Bolomey, R. A. and Wish, L. *J. Amer. Chem. Soc.*, 1950, **72**, 4483, 4486.
27 West, T. S. *Metallurgia*, 1951, **43**, 41.
28 Broido, A. E. C. D. 2616, 1947.
29 Sandell, E. B., "Colorimetric Determination of Traces of Metals." Interscience Publishers, N.Y., 1944.
30 Kolthoff, I. M. and Sandell, E. B. *J. Amer. Chem. Soc.*, 1941, **63**, 1906.
31 Irving, H. M. and Williams, R. J. P. *J. Chem. Soc.*, 1949, 1841.
32 Cowling, H. and Miller, E. J. *Ind. Eng. Chem., Anal. Ed.*, 1941, **15**, 145.
33 Fischer, H. and Leopoldi, G. *Z. anal. Chem.*, 1937, **107**, 241.
34 Martin, A. E. *Anal. Chem.*, 1953, **25**, 1853.
35 Baudisch, O. and Furst, R. *Berichte*, 1917, **50**, 324.
36 Kitahara, S. *Bull. Inst. Phys. Chem. Res., Tokyo*, 1948, **24**, 454.
37 Idem. *Ibid*, 1949, **25**, 165.
38 Irving, H. M. and Rossotti, F. J. C. *Analyst*, 1952, **77**, 801.
39 Saltzmann, B. E. *Anal. Chem.*, 1953, **25**, 493.
40 West, P. W. and Carlton, J. K. *Anal. Chim. Acta.*, 1952, **6**, 406.
41 Morrison, G. H. *Anal. Chem.*, 1950, **22**, 1388.
42 Fischer, H. and Bock, R. *Z. anorg. allgem. Chem.*, 1942, **249**, 146.

South American Aluminium

A NEW partnership between Canadian and Uruguayan interests to encourage and expand the use of aluminium and aluminium products in the growing markets of Uruguay was made known recently by the announcement that Aluminium, Ltd., will subscribe a one-third share interest in the principal aluminium fabricating company in that country—Elaboracion General de Aluminio Y Metales, S.A. The agreement provides that in addition to its cash investment, Aluminium Ltd. will supply technical assistance and know-how through engineering and fabricating specialists sent from North America, and where necessary through the training of Uruguayan personnel outside their own country. Aluminium Ltd. also will co-operate in the management of the enterprise to carry out eventual expansion programmes. The Uruguayan fabricating company was established in the 1930's and now produces aluminium sheet, foil and extrusions for local industry, as well as finished aluminium products for domestic consumption. Aluminium Ltd.'s officials said that aluminium consumption in Uruguay in 1954 was approximately 3,500,000 lb. and is expected to increase in the years ahead as the fabricating operation develops.

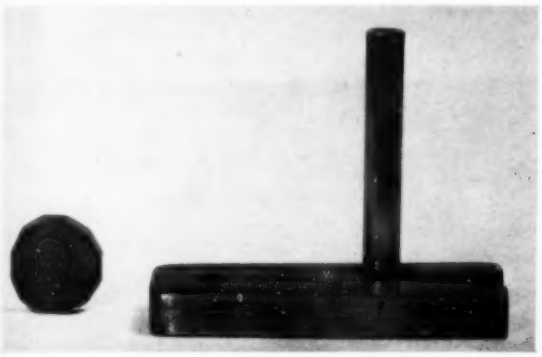
Correspondence

SPECTROGRAPHIC ELECTRODE HOLDER

THE Editor, METALLURGIA.

Sir,

Readers concerned with solution methods of spectrographic analysis may be interested in an electrode holder designed for use in the porous cup method of spectrographic analysis, which has been in use in this laboratory for some months and has proved very satisfactory.



In principle it is similar to a domestic spring peg, and the original was made from brass, with that part of the jaws actually in contact with the electrode made from stainless steel. The holder is thus relatively cheap and easy to make. Changing electrodes is simple and rapid as there are no screws to adjust. Some improvement could be achieved if the holder were made of copper and if the ends near the spring were covered with some form of heat insulator, which would further facilitate electrode changing.

I am indebted to Messrs. Sangamo Weston, Ltd., for permission to publish this information.

Yours faithfully,
J. HICKFORD (MISS),
Spectrology Department,
Sangamo Weston, Ltd.

Enfield,
Middlesex.

PLOTTING OF INVERSE RATE COOLING CURVES

The Editor, METALLURGIA,

Sir,

The apparatus devised by Cope and Kellett*, and described on page 54 of your January, 1956 issue, is similar in all essentials to that described by me in *J. Scientific Instruments*, 1951, **28**, 190. The earlier apparatus is in some respects an improvement over that described here, in that the motive power was provided by a standard meter motor, which contains the necessary gearing and costs very little. Where variation of speed is necessary (very rarely), this is obtained by using a driving pulley of a different diameter. I found, too, that merely pricking the gummed brown paper tape led to ambiguities and, therefore, provided a small spring-loaded punch of 1 mm. diameter, in place of the gramophone needle.

The earlier report also contains a description of a slide rule devised by Dr. J. L. Haughton, which is laid upon the plotting pad and through which the tape is threaded, so that it becomes possible, by inserting a pencil in the punched holes, to transfer the readings directly to the paper, moving the rule up one division for each transfer of the tape.

Yours faithfully,
E. F. MAILLARD,
Essex Aero, Ltd.

The Airport,
Gravesend.
13th February, 1956.

The Editor, METALLURGIA,

Sir,

We are indebted to Mr. Maillard for drawing our attention to his earlier paper. While agreeing that both pieces of apparatus operate on a similar principle, we would offer the following comments :—

(1) Our equipment was constructed for use in a teaching laboratory and is much simpler in design, using only one pair of driven rollers because the tape reel is tensioned by friction at the hub. It is compact and easy to use.

(2) We consider the electromagnetic punch an unnecessary refinement and have experienced no difficulty in obtaining a clean pin-prick with the needle supported on a thin flat spring over a rubber-faced platen.

(3) The ex-W.D. motor which we use is cheap and readily obtained. It is capable of a high torque so that with spring loaded rollers the drive is positive. Speed variation is an advantage when studying the influence of cooling rate upon transformations.

(4) The slide rule device for plotting the results is ingenious, but we consider that this operation can be most accurately and conveniently performed with a pair of dividers.

Yours faithfully,
LAWRENCE H. COPE, FRANK KELLET,
Department of Metallurgy,
Corby Technical College.

Corby, Northants.
21st February, 1956.

THE ISOLATION OF SILICON NITRIDE FROM A COMMERCIAL 4% SILICON STEEL

The Editor, METALLURGIA

Sir,

The Nitrogen Study Group of the British Iron and Steel Research Association, which over the past few years has been re-examining the whole problem of the chemical determination of nitrogen in steel, has recently isolated silicon nitride from a commercial grade of 4% silicon steel.

Two samples of nominally 4% silicon steel were analysed for nitrogen in the form of bar, and the results on both samples, using chemical fuming methods, were in good agreement amongst themselves and with those by the vacuum-fusion method, at about 0·005% and 0·013% respectively. The proportion of acid-resistant nitrogen was quite small, 0·001%, in both samples.

* It is suggested that in the publication of the description by Cope and Kellett the following references were omitted.
1 Rosenhain, W., *J. Inst. Metals*, **13**, 160 (1915).
2 Weaver, S.D., *J. Inst. Metals*, **56**, 209 (1935).
3 Earle, L.G., *J. Inst. Metals*, **72**, 403 (1946).

Another sample of 4% silicon steel was then analysed in sheet form, and the nitrogen figures determined chemically ranged between 0·001% and 0·002%, the residue separated by centrifuge failing to yield any significant amount of nitrogen on fuming. It was concluded from this work and the earlier results on the other samples of silicon steel that full nitrogen recovery had been obtained. However, when this sheet sample was analysed by the vacuum-fusion method at the National Physical Laboratory, it was shown that the true nitrogen content of the sample was 0·0055%, a result which was subsequently confirmed in other laboratories operating this method.

The sample which gave these anomalous results differed in two respects from the others. Firstly, it was in the form of sheet not bar, and secondly, no aluminium had been added during manufacture. Other casts, therefore, with and without aluminium additions, were analysed at various stages of production from ingot to sheet. With aluminium present the results were consistent throughout, but in its absence the chemical methods again indicated an apparent drop in the nitrogen content of the material in sheet form. The vacuum-fusion method showed, however, that the nitrogen content remained the same as in the earlier production stages. In the absence of aluminium, therefore, a large proportion of the nitrogen in this type of steel is converted into an acid-soluble form during the last reheating or hot-rolling operation.

The residue from the sheet specimens, obtained during chemical analysis, was not amenable to X-ray analysis, owing to precipitated silica, but, ultimately, by modifications to the solution procedure to avoid this precipitation, a clear X-ray photograph of the residue was obtained. The pattern was identical with that of synthetically prepared silicon nitride (Si_3N_4), and it is believed that this is the first time that this nitride has been positively identified in a commercial steel.

Silicon nitride has been found to be remarkably resistant to attack by acids, and the Nitrogen Study Group is now attempting to find ways of obtaining full nitrogen recovery from steels containing this compound by chemical methods. The most hopeful line of attack would appear to be to re-convert the nitrogen, by suitable heat treatment, into the soluble form in which it exists during the earlier stages of production.

Yours faithfully,
H. A. SLOMAN,
(Chairman, Nitrogen Study Group)

Metallurgy Division,
National Physical Laboratory.

Expansion of Aluminium Capacity in India

CONSTRUCTION work is expected to start this year on a new Canadian-backed aluminium smelter in India which will more than double that country's present aluminium production by 1958, officials of Aluminium, Ltd., disclosed recently.

Late in 1955, following lengthy studies and negotiation, Indian Aluminium Co., Ltd., decided to proceed with the erection of an aluminium smelter of 10,000 tons annual capacity at Hirakud in the State of Orissa. The smelter will be developed in conjunction with a new multi-purpose power project now nearing completion by the Government of the State of Orissa, and will be capable of further expansion to 20,000 tons capacity as conditions warrant.

New capital investment of approximately 75 million rupees ($15 million) will almost treble the company's present assets, and is expected to be financed by offerings in India of unsecured notes convertible into common shares, and through bank loans and retained funds. Aluminium, Ltd., which presently owns a majority interest in the Indian company, in partnership with 3,000 private local investors, has agreed to subscribe for 50% of the convertible notes.

This far-reaching decision is the latest and most important in a series of expansion moves which began with the establishment of Indian Aluminium Co., Ltd., in 1938. Since then the Indian company has created an integrated aluminium enterprise which mines domestic bauxite, produces alumina and primary ingot, and fabricates a wide variety of semi-finished products for the growing Indian market. Smelter capacity at the works in Travancore State has recently been doubled to 5,000 tons of aluminium ingot per year, and now partially meet the needs of the company's own rolling mills and extrusion plant, as well as other fabricators in the country.

Information on Canadian aluminium technique will continue to be supplied to the Indian company to support this expansion programme, which will also involve enlargement of alumina production and bauxite mining facilities.

For more than 25 years Aluminium, Ltd., has been active in the development of the Indian market, starting first with import sales activities and later branching into the manufacture of utensils and job-products until the creation of an integrated local industry could be justified. In recent years the company's activities have led to the introduction of aluminium in modern uses, such as transportation, electrical equipment and building. This has required the extensive training of Indian technicians, engineers and management at Aluminum Ltd's affiliates in Canada, Switzerland and the United Kingdom, as well as on the job by Canadian engineers. At the present time all but four of the 3,000 employees and executives are Indian.

Zeiss Mechanical Measuring Tools

THE name of Carl Zeiss of Jena has returned to the field of mechanical fine measuring tools available in this country following the appointment of The Selson Machine Tool Co., Ltd., and George Cohen Sons & Co., Ltd., as joint sole distributors in the United Kingdom. The Zeiss instruments which are now being offered for the first time since 1939 include both those with which industry was familiar before the War and a number of new models.

Fielden Midlands Office

Fielden Electronics, Ltd., recently opened a Midlands office at 18 Wolverhampton Street, Dudley, Worcs., with Mr. F. B. Price as engineer in charge. The new office will enable Mr. Price to offer improved facilities and services to his many friends in the region: his private telephone number remains Halesowen 1861.